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Dr. BOERHAAVE'S

Academical Lectures

ON THE

Theory of PHYSIC.

BEING

A Genuine Tranſlation of his

INSTITUTES

AND

Explanatory COMMENT,

Collated and adjuſted to each other, as they were dictated to his STUDENTS at the Univerſity of *Leyden*.

VOL. II.

Containing the Structure and Action of the *vital* or *ſanguificative* Organs; *viz.* the Heart, Lungs, Blood and its Veſſels, Glands, Brain and Nerves, *&c.*

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The Structure of the Arteries and Veins.

§. 131. THE red Liquor, called Blood, is found distributed thro' almost all Parts of the Body, and appears in its natural State to be contained in proper Vessels, or Tubes, term'd Arteries and Veins; or else in some intermediate Receptacles between those Vessels, such as the venous Sinus's of the Heart, Liver, and dura Mater, with the Auricles and Ventricles of the Heart, and the spongy Substance or Cells contained in the Parts of Generation of the Male and Female, and perhaps in the Spleen.

§. 132. The *Arteries* [1] appear to be membranous Canals of a *conical* [2] Figure, variously *ramified* [3] and inflected in oblique Directions; being smooth on their Inside, and without any *Valves* [4], except at the Heart; their smaller Branches arise from the larger Trunks *variously* [5], but generally in acute Angles towards their Extremities, seldom at right Angles, as in the Intercostals; and more seldom in obtuse ones, as in the umbilical Arteries of the Fœtus, *&c.* They consist of five Coats [6], as described by Anatomists; the most *external* [7] of which is thin and *nervous* [8] in its exterior Sur-

face, but internally it is compoſed of a very thick and vaſcular *Network* [9] of Arteries coming from the Coronary and other Branches, and interwoven with ſmall Veins, by which vaſcular Plexus the arterial Trunks are connected in their Situations. The ſecond is a thin and *cellular* [10] Coat, but very dilatable by inflating its Cells, wherein is naturally contain'd an oily Fat, which being preſſed out upon the muſcular Fibres of the next Coat, lubricates them, and renders them well adapted to perform their conſtant Dilatations and Contractions. The third, or *glandular* [11] Coat, is probably no more than Part of the former, conſiſting principally of the adipoſe Ducts and Cells, which immediately inveſt the fourth or muſcular Coat which is made up of annular Fibres, very ſtrong, *elaſtic* [12], and cloſely compacted together in ſeveral *Strata* [12*] one within the other, into which they are diviſible. The fifth and laſt Coat, which lines the internal Surface of the Artery, is thin and membranous, compoſed of longitudinal Fibres, capable of Contraction and Dilatation like the former. This whole Veſſel, while the Animal is alive and well, moves and beats with a vibratory Motion; but its *ſmaller Branches* [13] are variouſly diſpoſed and formed, ſo that the Structure of this Veſſel is very different in various Parts of the Body, both in the Size of its *Orifice* [14] ariſing from the larger Trunk, the Thickneſs of its Coats, Number of its Branches, and their different Inflections,

Inter-

Intertexture and *Distribution* [14] *, &c. The Extremities of these Arteries terminate either into the Beginnings of the small *Veins* [15], forming a continued *Tube* [16] with them, without any cavernous Medium; or else they are distributed to, and end in various Ducts, Cells, and large or small Cavities in several Parts of the Body, where they discharge or exhale a thin Liquor to mollify the Surface of the Membranes, and prevent them from growing together; while others of them end in *excretory Ducts* [17], or in particular *Sinus's* [18], as those of the Penis, Clitoris, and Spleen, or lastly, they are distributed *directly into secretory Canals* [19], or else into a glandular *Pulp* [20].

[1] The Name *Artery* is derived, (ἀπὸ τῆς τὸν ἀέρα τηρεῖν) from its containing Air; for the first Vessel thus denominated, was that we now call the *Trachea* or Windpipe, the Arteries themselves being in the early Times of *Hippocrates* termed *beating* or *internal Veins*, in Contradistinction to the external Veins, which have no Motion. But after *Hippocrates*, the Notion of *Erasistratus* prevailing, till it was refuted by *Galen*, that the Canals we now call Arteries, received a Quantity of Air in their Diastole from the Heart, which they expelled in their Systole; these Vessels were from that Time named *arteriæ*. This Air they supposed the Arteries received, from the left Ventricle of the Heart, which again took it from the Lungs; holding likewise, that the same Ventricle received but a very little Blood which transuded into it, thro' the muscular Septum of the Heart. At that Time they distinguished two Kinds of Air-vessels or

Arteries, arising from the left Side of the Heart; the one which we call the *Aorta*, they by way of Eminence named *arteria arteriosa*; the other, which appear to have the Structure of a Vein, they termed *arteria venosa*. The Veins were then defined to be those Vessels which came out of, and convey'd the Blood from the right Ventricle of the Heart: These they distinguished into the (φλεψ κοιλη vel μεγαλη, or) *vena cava*, and the (φλεψ αρτηριωδης, or) *vena arteriosa*, which last is what we now call the pulmonary Artery. This was the Doctrine received and taught in the physical Books and Schools, till the Time of *Harvey*, by whose Discovery, we are now enabled to remove the Error and define an Artery that Vessel which conveys Blood from the Heart to the other Parts of the Body, and a Vein the reductory Canal which returns the Blood sent by the former from all Parts of the Body, again to the Heart.

2 A Cone among the Mathematicians is defined a Pyramid, every transverse Section of which is circular; and in this Sense the Arteries are converging Cones: Since their Bases or Segments next the Heart, are always larger than those towards their Apices or Extremities in which they terminate; and accordingly the transverse Section or Diameter of every Artery, is less as it becomes more remote from the Heart. Yet we are not from hence to conclude, that taking the Aorta and its Branches as an Aggregate, its greatest Diameter must be nearest the Heart; for the transverse Sections or Diameters of all the smaller Arteries added together, will infinitely exceed the Diameter of the Aorta at the Heart: However, the Arteries may be reasonably termed conical, or converging Cones as to Sense: (1.) Because they have the real Qualities or Affections of such a Cone,

Cone, *i. e.* the Trunk or Basis next the Heart being distended, all its smaller Branches will be also dilated at the same Time; whereas if they had the Affections of a Crescent, or inverted Cone, it must follow, that the Branches would not be dilated, tho' the Trunk or Basis next the Heart be distended; nor does the Impulse of the Blood appear sufficient to dilate the Arteries, were they every where of an equal Diameter. (2.) Because the Aorta and every Artery taken without its smaller Branches, appear in all Respects to be really a converging Cone. Lastly, We wou'd rather have the Arteries termed *conoide* than conical, or real Cones; because all of them are more or less inflected, so as to describe some kind of Arch or Angle: But this they cannot do, without changing the Axis of the Cone, from being perpendicular to its Basis; and therefore they cannot be strictly termed Cones.

3 All the Arteries, traced down to the very minutest, appear to be thus more or less ramified; though some of them run entire, a considerable Length before they divide, as we commonly observe in the Carotids, from the Aorta to their thyroide Branches.

4 There is no Artery in the Body, in which the Blood has not a free and ready Passage into any of the rest; and the Artery itself will even become a Vein, and return the Blood back again to the Heart, if the impelling Force be greatest at its Extremity; upon which Principle, I have seen the Body of a male Infant, injected by a small Artery in the Groin, so as to fill the whole arterial System very exactly.

5 This Variation of their Rise is manifold, differing, (1.) According as their Trunks are nearer to, or more remote from the Heart. 2. As

ſome ariſe from the anterior Part of the Aorta, like the Spermatics; others from its Sides, in oppoſite Directions, as the Intercoſtals, and Coronaries; and others again ariſe more laterally, as the inferior meſenteric Artery, &c. 3. According to the Angle which the arterial Branch makes with the Trunk from whence it proceeds: Thus ſome Arteries with their Trunks intercept a very acute Angle, as the Spermatics; others intercept an Angle of about 45 Degrees, which is the moſt frequent among them; and others again ſtrike off in right Angles, as the Emulgents. And laſtly, Some Branches with their Trunks, make an obtuſe Angle, as the coronary Arteries of the Heart with the ſpinal Arteries which ariſe from the vertebral, and deſcend through the middle of the ſpinal Marrow; for the vertebral themſelves are only diſtributed on the outſide thereof. Theſe are the principal Differences of their Origination, and which merit our Notice, becauſe thoſe Parts of the Blood which are the moſt ſolid and move with the greateſt Velocity, always endeavour moſt to continue in the ſame Courſe in which they were at firſt moved; while the lighter Particles of that Fluid which have the leaſt Denſity, paſs off at more right Angles.

6 The larger Trunks only, have all theſe five Coats, before they are diſtributed into any Part; for when an Artery enters into any Viſcus it puts off the exterior Tunic; and when the Arteries enter into the Bones, they even put off their muſcular Tunic as well as their exterior one, ſo that within the Cavities of the Bones they become almoſt thinner than the Veins.

7 This external Tunic is derived to the Aorta, partly from the very thin Membrane which cloſely inveſts the muſcular Fibres of the Heart externally,

and

and in Part from the Pericardium and Pleura; but after the Trunk of the Aorta has passed thro' the Diaphragm, it in like manner receives its external Tunic from the Peritonæum, and the other common Membranes of the several Cavities thro' which it passes.

[8] It is termed nervous, not from its being either extremely sensible, or plentifully supplied with small Nerves; but because it appears white, its Blood-vessels escaping the naked Eye, unless they are distended with some Injection.

[9] This Net-work of small Arteries, which is pretty thick, comes from the Coronaries, and invests the whole Superficies of the Aorta near the Heart, immediately under the nervous Tunic. This appears from the Experiments of *Ruysch*, whose fluid ceraceous Injection has filled the left Auricle and Ventricle of the Heart, so as to pass into its coronary Arteries, and render all their small Branches, spent on the Coats of the Aorta, very conspicuous. A remarkable Peculiarity of this Plexus is, that it is filled, or in its Diastole, when the Aorta is in its Systole, and emptied when the Aorta is in its Diastole; and therefore the Contraction and Dilatation of this arterial Plexus must be always made in opposite Times to those of the Aorta, and at the same Times with those of the coronary Arteries. (§. 183.) For when the Aorta is fullest of Blood, at that Instant only does it fill both the coronary Arteries; and at the same time, when the muscular Coat of the Aorta contracts, the cellular one does not, having no such contractile Power; so that by this Means there is made a Dilatation or Space betwixt the muscular Coat contracting itself towards the Axis of the Aorta, and the external nervous Tunic, into which Space the Blood rushes by the coronary

Arteries, ſo as to fill all their ſmall Branches ſpent on the Aorta; by which Repletion of the Arteriolæ the Contraction of the Aorta is alſo further augmented. But when the Aorta, after its utmoſt Contraction, is again filled by the Syſtole of the Heart, with more Blood from its left Ventricle, its muſcular Tunic will be then diſtended, ſo as to compreſs and empty the ſmall Veſſels ſpread upon it; which therefore cannot at that time receive any Blood in them from the Coronaries, which are alſo at that inſtant empty.

10 This cellular or adipoſe Membrane, in whoſe Subſtance run the ſmall Veſſels of the preceding Plexus, being interpoſed betwixt the nervous and muſcular Coat, prevents them from growing to each other, and pours out its lubricating Oil upon the Fibres of the latter, which are perpetually in Motion.

11 They are protuberant Corpuſcles, appearing in the cellular Tunic, which ſeem to afford a lubricating Mucus; or they are perhaps no more than diſtended Veſiculæ in the ſame adipoſe Membrane next to the muſcular Tunic.

12 * One may by Patience and Maceration ſeparate almoſt an hundred of theſe Strata or Lamellæ in the Aorta of an Ox; in which this muſcular Coat is near two Lines thick.

12 Such is the Elaſticity of the Aorta, that it will receive above an hundred Pints of Water, without burſting; by which Power it is, that the Arteries continue to contract and leſſen their Diameters even after the Heart has ceaſed to move, ſo as to diſcharge almoſt all their contained Blood into the Veins; which therefore appear livid and conſpicuous, while the Arteries are in a manner empty and contracted in the dead Subject.

13 It was a great Error in the learned *Bellini* and *Malpighi*, to consider all the Extremities of the Arteries as a Network of Vessels dividing and again terminating into each other in the same Manner; upon which Supposition the former has built a System with more Ingenuity than Truth. 'Tis indeed certain, that in the Heart and Lungs the Arteries barely ramify, and then immediately return again in Veins; but the great *Ruysch* seems to have been the first who has demonstrated that the extreme Branches of the Arteries, are differently disposed in almost every different Part of the Body. In the Liver they appear like small Pencil Brushes, in the Testicles they are wound up like a Ball of Thread, in the Kidneys they are inflicted into Angles and Arches, in the Intestines they ramify like the Branches of Trees, in the Uvea they form Circles and Radii, in the Brain they are waved in and out in a serpentine Course; in the Omentum they are disposed something like the Marshes of a Net, and in almost every other Part of the Body they assume a different and peculiar Structure.

14 The Sections of the Arteries as they arise, do not decrease in an inverse Ratio to their Distances from the Heart, as they must if they were framed mechanically by the Impulse of the Blood, according to the Opinion of *Cartesius*. On the contrary, the very first Arteries we meet with, the Coronaries, are but small, when the very next are the large carotid and subclavian Branches; after which come the little Twigs to the Thimus and the Intercostals, then the large Mesenteric, Cœliac and emulgent Branches, and immediately after them the slender spermatic Arteries: From whence it is manifest, that the human Body was not formed by a spontaneous Mechanism, but

that

that its Parts were thus built for the designed and foreseen Uses intended them by the most wise Creator.

15 When a small Artery is near spent, it sends off many little Branches; at each of which its Membranes are put off, or render'd thinner, till at last, where they become smallest, thinnest, and without Branches, they acquire a cylindrical Figure; and then nothing more is required for its becoming a Vein, but that it be reflected back again.

16 In this Manner terminate most of the Arteries spent upon the membranous Parts, where there is but little Secretion, according to the Demonstration of *Lewenhoec*.

17 Of these there are various Kinds, the most numerous are those which exhale the perspirable Matter of *Sanctorius*, being seated wherever the Skin is extended. Those excretory Tubes being dilated by the Humours receiving a greater Impulse from the Motion of the Muscles, *&c.* do then transmit the brackish and aqueous Part of the Blood, which we call Sweat; and by urging the Circulation more violently, they will discharge the very Serum itself, which will concrete; but they never transmit the Cruor, unless it be in Women, when the hypogastric and spermatic Arteries being distended from a Plethora, discharge the menstruous Blood periodically this Way. There are another Set of excretory Ducts which do not discharge any thing out of the Body, but only exhale a thin Vapour into several Cavities, some of which are very small, and only large enough to receive Parts, or allow them Motion; others of these Cavities are much larger, as the Ventricles of the Brain, the Cavity of the Pericardium, Thorax and Abdomen. That there are such excretory

cretory Ducts in those Cavities, is apparent from Injections escaping into them that Way; and it is also as apparent, that this Moisture must be again absorbed, otherwise it would be turned into a Water.

18 The Blood is for a Time found in a manner extravasated in some Parts; as when in the venereal Act it is pour'd out of the patulent Orifices in the Arteries into the spongy Substance in the Parts of Generation of both Sexes, and then again returned by absorbing Orifices of the reductory Veins.

19 The small Arteries terminate sometimes in cylindric Vessels or Ducts, which have no intermediate Receptacles, but discharge their secerned Liquor immediately into the Cavity for which it is designed. Thus it is in the villous Coat of the Intestines; in the *tubuli Belliniani* of the Kidney, which convey the Urine from the Arteriole strait into the Pelvis and Ureter; and possibly the same Mechanism may obtain in the Uterus. Other small Arteries again, let their secerned Fluid drain into some Receptacle, in which it stagnates, thickens, and meliorates; as the Bile in the Liver, the Semen in the Epididymis, and all glandular Juices in their Folliculi.

20 As is the Case in most of the Viscera; but whether this Pulp is made up barely of small Vessels spun out to a great Fineness, or whether it is composed of Folliculi or Cells, upon which the small Arteries are spent and ramified, is the Subject of another Consideration. See §. 264 and 265. But this is certain, that not any of the Arteries terminate in blind Ducts that have no Passage; for if that were the Case, the Blood's Circulation wou'd be soon brought to a Period. Nor is the Blood extravasated from any of the Arte-

ries,

ries, so as to stagnate and form the Parenchyma of the Viscera, as the Ancients imagined. It was indeed the Opinion of *Ruysch*, that the Blood transuded thro' the Pores of the Vessels like Dew, in order to nourish the solid Fibres; into which Notion he was led by the following Appearance: Having accurately filled a Heart with a soft Injection like Wax, he cut it open, and dipt it in *Oleum Terebinthinæ lavendulatum* (which leaves a glossy Varnish upon prepared Parts, that preserves them from any Danger of Putrifaction or Decay:) Some Time after, viewing it in the Sunshine, there appeared red Spots within Side of it. These Spots, said *Ruysch*, are the Injection extravasated under the Varnish, without any Rupture or Injury offer'd to the Vessels, just in the same Manner as the Blood transudes in the living Subject. But for my own Part. after carefully examining that Preparation with the utmost Attention, I am persuaded that those Spots were in reality the Penecilli of the Vasa Exhalantia, each of which were so turgid with the Injection, as to appear together in the Rays of the Sun like one continued Spot.

§. 133. The *Veins* [1] have almost the same Figure and Distribution with the Arteries, only formed with *a larger Capacity* [2], and generally *more in Number* [3]; but all of them have their Membranes or Coats much *thinner and weaker* [4] than those of the Arteries. *Valves* [5] are also frequent in the Veins, which are generally single at the Insertion of the venal Branches into their larger Trunks, being oblong, and almost shaped like the Finger of a Glove;

Glove; but in the perpendicular Trunks of the larger Veins, at ſome Diſtance from the Heart, they are generally placed two together, to promote the Aſcent of the Blood in its perpendicular Courſe; and ſuch is their Structure and Connection within the Veſſels, that they admit the Blood to paſs forward from the ſmaller Branches into the larger Trunks, but prevent its Regreſs whilſt the Heart is contracted, and ſuſtain its Weight. The Veins in the living Animal have *not naturally any Pulſation* [6], nor any throbbing Motion like that of the Arteries. Their ſmalleſt Extremities ariſe variouſly, as thoſe of the Arteries were obſerved to terminate differently; ſome of their Anaſtomoſes or incipient Roots coming from the *bibulous Pores* [7] in the Cuticle; others from the *abſorbing Ducts in the thin Membranes* [8], which line all the internal Cavities of the Body, great and ſmall, forming *Cryptæ* and *Folliculi*; and others of the incipient Veins ariſe immediately from the Extremities of Arteries, or elſe from analogous Ducts, or Sinus's, like thoſe of the Penis, Clitoris and Spleen; or, laſtly, from a glandular Pulp.

[1] Tho' the Veins receive all their Blood from the Arteries, yet they alſo abſorb ſome thinner Juices from many other Veſſels; but I cannot think a Patient can receive any Benefit from a Bath of Blood, recommended by the Ancients. There are indeed ſome Arteries without their corrreſponding Veins, as thoſe which convey blood into the Uterus.

The

[2] The Veins are often three or four times as large as their correſponding Arteries, and ſometimes larger, as in the Emulgents. So alſo the Sinus of the Vena Cava vaſtly exceeds the Dimenſions of the Aorta at the Heart. But tho' there is, by this means, more Blood running at once in the Veins than in the Arteries, yet a greater Quantity paſſes the Arteries in a given Time than the Veins; for the Impulſe or Momentum of the Blood in the latter being much weaker, it there moves ſlower, and occaſions an Enlargement of this weaker Veſſel; or, which is the ſame, if equal Quantities of Blood paſs into and from the Heart in the ſame Time by the Vena Cava and Aorta, it muſt in the firſt paſs three times ſlower than in the laſt, becauſe the Diameter of the Vein is thrice that of the Artery. There was a Neceſſity for the Veins to be made much weaker than the Arteries, that they might not too much reſiſt the Action of the latter, but give way and receive their Blood, as alſo an additional Quantity of Chyle. But yet the Veins are not ſo much larger than the Arteries as they commonly appear in Diſſections; for after Death the Arteries continue to contract themſelves by their greater Strength, aſiſted with the Cold, and diſcharge their Blood into the leſs reſiſting Veins, by which means the latter appear diſtended beyond their natural Dimenſions in Life, while the Arteries are as much leſs or more contracted.

[3] One Example we have of two Arteries to but one Vein, in the Navel-ſtring of the Fœtus; but even there the one Vein much exceeds the Diameter of the two Arteries. But if we inſpect the Meſentery, and moſt of the Viſcera, we ſhall find them much larger and more numerous than their Arteries. Some Veins there are without a correſponding Artery, as the Vena Azygos, *&c.* Laſtly,

There

There are an infinite Number of bibulous Veins, which greatly exceed the Size and Number of their correſponding Arteries. Conſider how readily Water enters into the Diver ſo as to make him ſwell, and abate his Thirſt without drinking, with the Experiments at *Note* 12. to §. 87.

4 The Fibres of their Tunics, tho' of the ſame kind with thoſe of the Arteries, are much weaker, and leſs elaſtic. The Veins have their Coats the thinneſt where they ariſe from the Arteries; from whence they become ſtronger and thicker as the Veins enlarge, till at the Heart they are near as ſtrong as the Coats of an Artery. This holds true as well of the Trunk and Branches of the Porta, as the Cava; for the Branches of the meſenteric Veins are the more robuſt as they are nearer their Heart, or Sinus of the Trunk of the Porta; which laſt, where it ramifies in the Liver, is exceeding robuſt like an Artery, which it then every way reſembles.

5 Theſe Valves were formerly obſerved by *Fabricius ab Aquapendente*, tho' he could not aſſign their Uſes. They are found in the Veins at the Heart, at the Inſertion of the Vena Azygos into the Cava, at the Entrance of the thoracic Duct into the Subclavian, at the Liver, at the Opening of the Emulgents, and in the Veins of Limbs. Their Office is to ſuſtain the Blood, and prevent it from returning back in the Veins, while it is not admitted forwards into the Heart, during its Syſtole; but when the right Ventricle is relaxed, ſo as to receive the Blood which then comes forward, the Valves open and propel it to the Heart. Theſe Valves are alſo frequent in the Veins of the upper and lower Limbs, as they are there very neceſſary; becauſe the Blood would from its Weight, ſlow Motion, and the Cold, become ſtagnant if its Courſe

Courſe was not thus promoted. As for the Valves placed at the Opening of venal Branches into their Trunks, they ſerve chiefly to prevent the Blood from returning out of the Trunks into the Branches, which wou'd overcharge the latter, when the former are preſſed in ſtraining, *&c.* Which laſt is alſo the Uſe of thoſe Valves found in the Sinus's of the dura Mater, at the Entrance of the Veins from the Pia Mater, which prevent the Blood from returning back out of the former into the latter. Laſtly, Thoſe in the jugular Veins, at their joining with the Subclavians, prevent the Regreſs of the Blood in the ſame Manner, and for the ſame Uſes.

[6] But when the Veins are tied or obſtructed in any Part, they are ſomewhat agitated by the Impetus of the Blood, drove on by the Arteries againſt the Obſtacle : and this occaſions that throbbing Motion in them, which is ſometimes perceptible in Inflammations.

[7] Abſorbing Veins are found diſtributed in all Parts which have any exhaling Arteries. Among ſuch Veins we may reckon thoſe that abſorb the aqueous Humour of the Eyes ; for if that be diſcharged, it will be again reſtored in twenty-four Hours ; which argues, that the Separation of this Humour from the Arteries is made very ſwiftly ; ſo that it wou'd be accumulated in vaſt Quantities, if it were not returned by the abſorbing Veins with the ſame Velocity that it is ſecerned from the Arteries.

[8] All the Juices in the Body become thicker than they were ſecreted, barely by ſtagnating with the Diſſipation and Abſorbtion of their more fluid or aqueous Parts ; which have no other way of eſcaping out of the internal Cavities, but by entring ſmall bibulous Veſſels, which return them into the ſanguiferous Veins. The Semen, for Example, at its

its first Secretion in the Testicle, is as fluid as the Tears; but it this way becomes inspissated into a perfect Glue in the seminal Vesicles. Lastly, in the Thorax, Abdomen, and all other Cavities of the Body, which are supplied with a vapoury Dew discharged from the patulent Arteries, (and which upon opening Animals lately kill'd, has a very disagreeable and peculiar Smell) there must of necessity be other absorbing Veins to return or discharge the same.

§. 134. Every one of these Arteries, (§. 132.) which are found dispersed throughout the whole Body, do all of them join and communicate by an open and free Passage, to the Body one way, and to the Aorta the other; the Trunk of which last arises from the left Ventricle of the Heart: But those Arteries which compose the Lungs arise in the same manner from the *Pulmonary Artery* [1], whose Trunk comes from the right Ventricle of the Heart; which we are taught from the Appearance of both those Vessels, when distended with cerations *Injection* [2]; but the Ancients traced them without that Artifice, tho' they could not descend to their ultimate Branches for want of it. Lastly, The Orifice of the Aorta and Pulmonary Artery at the Heart are of equal Dimensions.

[1] The Compages of Arteries in the Lungs has undoubtedly the same Mechanism with that of the other Arteries of the Body, as they are divided into the same different Orders or Series: From the sanguiferous Branches of the pulmonary Artery

arise serous Arteries, as in the other Parts of the Body; from the serous arise lymphatic Arteries, which again arise from each other in lesser Orders. The Lungs have also their Nerves, and all the Species of Vessels that are found in other Parts.

[2] This curious Artifice, which was contrived by that industrious Naturalist Dr. *Swammerdam* before 1666, has been since so much cultivated and improved by the celebrated *Ruysch*, that his Preparations have surprised even the most learned Part of Mankind. We are by this means enabled to view the whole arterial System from the Heart, even to where their smallest Twigs join with the incipient Veins; hereby we trace them into the exhaling Vessels, into the Villi of the small Intestines, and into the pulpy Substance of the softest Viscera. The larger Branches of the Blood-vessels have indeed been traced with surprising Exactness, by Excarnation only, by the indefatigable Pains of *Eustachius*; and this he has done to such a Degree of Perfection as may astonish our Moderns, since it does not appear that he used any Injection.

§. 135. All the Veins (§. 153.) dispersed thro' the whole Body are found, like the Arteries, to open into one Trunk, call'd the Vena Cava; which forming a large Sinus, cover'd with Membranes almost like those of an *Artery* [1], does thereby terminate in the right Auricle and Ventricle of the Heart. But the pulmonary Veins, forming four large Branches, terminate in a Sinus, almost like that of the Cava, which opens into the left Auricle and Ventricle of the Heart. There is also a different

rent Mechaniſm in the Veins of the *Liver* [2], which we ſhall explain when we come to that Viſcus. Laſtly, Theſe two capital Blood-veſſels (§. 134, 135.) are largeſt at the Heart; from whence they gradually diminiſh in their Diameter as they paſs to the ſeveral Parts of the Body, which is generally in cloſe Company with each other. The Area of the Opening of the Vena Cava and its Auricle into the right Ventricle, is to that of the pulmonary Artery opening in the left, as 47 to 114.

[1] By which Coats the Strength of the Cava in this Part becomes almoſt equal to that of the Aorta: It was neceſſary it ſhould be thus ſtrong here, to ſuſtain the Weight of the ſuper-incumbent Blood, with an additional Preſſure from the Heart in its Syſtole.

[2] At this Viſcus the ſplenic and meſenteric Veins unite into one Trunk, which opens into a ſtrong muſcular Sinus, from whence the Blood is detached into the Liver by its converging Branches like Arteries, in order for the Secretion of Bile. *Vid.* §. 350.

Of the Circulation of the BLOOD.

§. 136. IF any of the larger Arteries of a living Animal be conſiderably wounded, almoſt the whole Quantity of Blood neceſſary to keet it *living* [1] will be expell'd from thence with a great *Force* [2], and in a few

Minutes Time, as we are convinc'd from the common Practice of Butchers.

[1] The Maſs of Blood will not indeed be totally diſcharged by the Wound, becauſe ſome will remain in the Veins; for when ſo much of the Blood's Quantity or Motion is deſtroy'd as is neceſſary to keep the Animal living, the Effect is inſtant Death; which is the Meaning of *Moſes* when he ſays, that *the Life or Soul of the Brute is in its Blood*, for which Reaſon he ranks it among the prohibited Food; but the true natural Reaſon ſeems to be, that in thoſe warm Regions the Blood is very ſpeedily apt to putrefy, and afford a Nouriſhment too alkaline; yet there may be a religious Reaſon beſides.

[2] The *Jews*, who are forbid to eat any Animal that is kill'd by Diſeaſe, have, from a Tradition of the Rabbins, conſtantly eſteemed the killing by Contuſion and Fracture, or knocking down, amongſt the Tribe of Diſeaſes, thinking that kind of Death only unaccompany'd with Diſeaſe, which is made by Wounding or Inciſion; and accordingly when they kill an Ox, *&c.* they draw up the Head of the Animal to ſtretch its Throat, which with a ſharp and long Knife they ſuddenly divide ſo as to cut thro' the jugular Veſſels, whereupon the Blood ſuddenly flows with great Impetuoſity to the Quantity of about 30 Pounds, which ſpeedily ends the Life of the Animal. So great is their Superſtition in this reſpect, that the Edge of the Knife muſt be firſt tried upon the Nail of the Thumb before they uſe it; for if it appears rough or ſerrate, the Ox will not be judged eatable. In *Spain* they have nearly the ſame Method of executing Criminals capitally convicted; for the Hangman having reclined their Head backwards,

cuts

cuts thro' their Windpipe and large Blood-veſſels of the Throat. I chuſe to offer this Example, becauſe in this Method the Animal does not die apoplectic, as the Oxen do who are kill'd after the common Method of *Europe*.

§. 137. Nor does it much ſignify in this Experiment (§. 136.) *in which of the Arteries* [1] the Wound be inflicted, as we are aſſur'd from the *living Diſſections of Dogs* [2], and the Wounds in Men.

[1] Provided it be tolerably large; tho' we have ſeveral Inſtances of fatal Hæmorrhages even from ſmall Arteries, which cou'd not be cloſed or compreſſed, as in the Noſe, or in the ſmall Artery of a Tooth, *&c.*

[2] The Great *Harvey* thus diſſected many kinds of Animals with a View of making Experiments. But the preſent Argument is moſt elegantly confirmed by an Experiment of *Drelincourt*, who after tying down a Couple of Dogs, made an Inciſion in the crural Artery of one, and in the carotid Artery of the other, and they both expired nearly within the ſame ſhort Space of Time.

§. 138. From hence it follows, that all the Blood of the Animal thus wounded, is moved with great Strength and *Swiftneſs* [1]; as will appear more evidently, if all the ſound Arteries are ſecured by *Ligature* [2], while the Blood flows from the wounded Artery.

[1] Swift indeed, ſince ſo large an Animal as an Ox expires by loſing 30 Pound of Blood in eight Minutes Time. But the Blood is not moved with

this Velocity from the Wound, for that has no moving Power to haſten the Courſe of it; the Blood muſt therefore flow thus ſwiftly from the wounded Artery, becauſe it before moved with a great Velocity within the Arteries; ſince in the dead Animal, or one that is dying, it ceaſes thus to flow.

[2] For then none of the Blood cou'd paſs through the tyed Arteries into the Veins, but it wou'd be all forced thro' the wounded Artery.

§. 139. It is therefore apparent that the Blood has a ready Paſſage, from every Part of the Body that contains it, into any one of the Arteries [1].

[1] For all the Blood, except a ſmall Part in the Veins, is diſcharged from the wounded Artery, (§. 236.) which (§. 137.) may be in any Part of the Body; ſo that all the Blood of the Arteries will be evacuated, and the greateſt Part of that in the Veins: Therefore the Blood has a ready Paſſage from all the Arteries of the Body, and alſo from all the Veins, into any one Artery. There is therefore a free Paſſage for the Blood out of all the Veins, into all the Arteries; which Phænomenon contradicts the Opinion of the Ancients, *viz.* that the Blood paſſes out of the Heart into the Veins, and by them into all Parts of the Body, for Nutrition; but if the Blood paſſed by the Veins, as by Arteries, into the ſolid Parts to nouriſh them, how ſhould all, or the greateſt Part of the venal Blood be diſcharged by the wounded Arteries. The Phænomenon rather ſhews, that the venal and arterial Blood are the ſame; and that it does not ſtagnate or extravaſate

ſate in the Parts, but is directly carried out of the Veins into the Arteries.

§. 140. Therefore as the whole Maſs of Blood flows out impetuouſly thro' the wounded Artery, it muſt needs have paſſed ſwiftly through the Veſſels before the Wound was inflicted.

§. 141. Again, If any Artery be laid bare and tyed with a Thread paſſed round it, the Artery then ſwells and beats betwixt the Ligature and the Heart; but becomes flaccid and without Motion betwixt the Ligature and its Extremity, and at the ſame Time the pervious Arteries adjacent to that which is tyed, are found to beat more violently: If now the Artery be inciſed betwixt the Ligature and the Extremity, little or no Blood follows; but if you open it betwixt the Ligature and the Heart, it continues to ſend out a ſwift and ſtarting Jet of Blood till the Animal expires. But the Artery for this Experiment ought to be ſingle, or by itſelf, and without any Communication beyond the Ligature, by *Anaſtomoſis* [1], with any other adjacent Artery.

[1] Of which kind there are uſually many Communications of the Arteries in the extreme Parts of the Limbs. By ſuch Anaſtomoſis it may indeed happen, that the Blood paſſing out of the free into the tyed Artery, it will flow out beyond the Ligature, if the Anaſtomoſis was beyond it; for which Reaſon a Ligature is order'd

to be made above and below the Artery in the Operation for an Aneuryſm. The carotid Arteries have alſo frequent Communications or Anaſtamoſes with each other, and with the cervical or vertebral Artery; ſo that upon tying or wounding either of them, the Blood will paſs out of one into the other.

§. 142. From whence it appears, that the Blood in a living Animal, has not only a Motion in the Arteries, but alſo that its Motion or Flux is directed from the Heart to the Extremities, and that it is diſtributed to all Parts remote from the Heart both external and internal by theſe Veſſels; ſo as to paſs from the Trunk to the Branches, or *from a greater Diameter to a leſs* [1]; and in this manner the whole Maſs of Blood may be derived into and diſcharged from any one of the Arteries, but not the contrary way.

[1] That the Blood takes this Courſe as well in the ſmalleſt Arteries as in the larger Trunks, is alſo apparent to the very Eye, when armed with a Microſcope, according to the Demonſtrations of *Lewenhoek*.

§. 143. If any one of the larger Veins be in like manner (§. 141.) laid bare and tyed with a Thread, it ſwells betwixt the Ligature and the Extremity without any Pulſation, but appears empty and flaccid betwixt the Ligature and the Heart; If now the Vein be opened betwixt the Heart and Ligature, little

or

or no Blood follows, but if inciſed betwixt the Ligature and Extremity, the Blood continues pouring out till the Animal either faints or dies. Nor is one Vein of more Conſequence than another for this Experiment, as we are aſſured from *Phlebotomy* [1].

[1] In this Operation, upon making a Ligature on the Arm, betwixt the intended Orifice and the Heart, the Blood is accumulated in the Vein, and runs out faſter from the Wound; but it is not the Blood in the Hand only which is thus let out, for that Part weighing not much above a Pound, is incapable of yeilding near two Pounds of Blood. We have indeed an Objection made by ſome, which is no more than a Falacy: *viz.* That when the Ligature has been made a while on the Arm in Phlebotomy, the Blood frequently ceaſes to flow from the Vein thus inciſed; which they think argues againſt the Blood's moving in the Veins from the Extremities towards the Heart. We know that this Accident does ſometimes happen in Bleeding, but then it proceeds from the Arteries lying too bare, or the Ligature being too tight, ſo as to compreſs the Artery as well as the Vein, by which means the Blood cannot paſs out of the former into the latter; which therefore does not appear at all diſtended, and yields no Blood from its Orifice; but ſo ſoon as you ſlacken the Ligature, the Blood follows plentifully.

§ 144. It therefore follows, that the Blood flows ſwiftly from all Parts of the Body into the inciſed Vein; and that the Direction of its Courſe in the Vein is from the leſſer to the larger

larger Diameter of the Veſſel, from the Branches to the Trunk, or from the Extremities towards the Heart: And that the Blood moves thus and no other way in the Veins, is alſo apparent from the Valves. (§. 133.)

§. 145. Hence it is ſufficiently evident, that the vital Blood is continually carried with a ſwift Motion thro' all the Arteries of the Body, and that its Courſe in them is from the left Ventricle of the Heart thro' the Trunk of the Arteries into their Branches, and by theſe into all Parts of the Body, both external and internal.

§. 146. But on the contrary, all the Veins, except the Porta in the Liver, return the Blood conſtantly from all Parts to their Branches, and from their Branches into their Trunks, from whence it paſſes in the right venous Sinus, and partly into the right Auricle.

§. 147. For the Blood brought into the venous Sinus may be drove from thence, by its muſcular Coat into the right Auricle, when relaxed; ſince there is then no Reſiſtance, and its Progreſſion is forwarded by the Impetus of the ſubſequent venal Blood urged on to that Part.

§. 148. But ſince both the right and the left Auricle of the Heart is each of them a large hollow Muſcle, furniſhed with many ſmall Arteries and Veins, and compoſed of two Rows of ſtrong Fibres running in contrary Directions into oppoſite Tendons on each Side;

Side; one Tendon of the right Auricle being inſerted into the venous Aperture of the right Ventricle, and the other Tendon, which is firmer, terminating circularly round the Cava; it is apparent, that by the contractile Force of this laſt, the Blood may be expelled with a conſiderable Impetus into the right Ventricle, when relaxed.

The right Auricle is near ten Times larger than the left; but then the right Sinus, or that of the Cava, is much leſs than the left Sinus of the pulmonary Vein; the Reaſon of which ſeems to be founded on the Office of the Auricles, being partly to attenuate the Blood, or prevent its Concretion: For the Blood in the right Auricle being leſs fluid than that which has paſſed the Lungs, it was neceſſary that more of it ſhould ſuffer the Action of the Auricle at the ſame time; whereas the left Auricle being leſs than the right, is accompanied with a larger venous Sinus, that it might be able to receive the ſame Quantity of Blood which was diſcharged from the right Auricle and Sinus together.

§. 149. For the right Ventricle of the Heart being then empty becomes longer, and the three tricuſpid Valves are drawn back towards the Sides and towards the Apex of the Heart, whoſe two muſcular Sides of the right Ventricle, from whence thoſe Valves ariſe by round muſcular Proceſſes or Papillæ, are at the ſame time dilated or moved back to each Side, ſo that a Paſſage being thus opened to the

the Blood, there remains no Obſtacle to hinder it from taking this Courſe.

The tricuſpid Valves are confined to their Seats in the Heart by the muſcular Proceſſes and tendinous Cords which aſcend out of its Apex; whence it happens, that when the Heart is elongated, theſe Valves are drawn down towards its Apex and Sides, by which means they make a free Paſſage for the Blood into the right Ventricle.

§. 150. What we have here advanced is alſo confirmed by Inflations, Injections, the anatomical Structure of the Parts, and their Appearances in living Diſſections.

That theſe Parts act in the Manner before deſcribed, may be made appear even to the Eye by opening a living Dog; and if you blow Wind by an Inciſion into the right Ventricle, it will not diſtend or paſs into the Cava, becauſe by elevating the tricuſpid Valves, its Paſſage thither is excluded.

§. 151. The right Ventricle being thus filled with Blood, does, by the Contraction of its Fibres, alſo preſs out the Blood from the coronary Veins which open into this Ventricle, and mixing them together, continues to urge the ſame ſtrongly in all Directions, and particularly towards the Apertures of its Cavity; by this Means the Blood riſing up by the Sides of the ſame Ventricle, catches hold of, and elevates the tricuſpid Valves, which are ſo connected

the Blood cannot pass thro' the Lungs to fill the left Ventricle, tho' the right be at the same time plentifully supplied: For which Reason we usually find in People who die suddenly, that upon opening them, the right Ventricle is full of Blood, while the left is empty.

§. 160. From what has been said, it therefore appears that all the Blood returning from every Part of the Body, (as well external as internal, not excepting that of the Heart itself and its Auricles) is drove into the right Ventricle of the Heart, out of which it is forced thro' the Lungs into the left Ventricle, and from thence by the Arteries thro' every individual Part of the Body, from whence it returns by the Veins to the Heart again. This is the uninterrupted Course of the Blood's *Circulation* [1], the Glory of which Discovery, with the Proofs and Explanation of it at large, is due to the immortal Name of Dr. *Harvey* [2]: The Truth of which Circulation is also confirmed by *Injections* [3], *Transfusions* [4], and even to the Eye itself by the *Microscope* [5].

[1] We have hitherto demonstrated a threefold Humour returning to the Heart, *viz.* the venal Blood, the Chyle poured into it by the thoracic Duct, and the several Juices absorbed by the bibulous Ducts throughout the Body, which lead to the Veins. This mixt Fluid of the Veins is received into the right Ventricle of the Heart, which forces it into the Lungs, and thence into the left Ventricle, which propels it thro' all Parts

of the Body by the Arteries. As the Truth of this Syſtem is founded on Experiments, by which we are let into the Boſom of Nature, let us gratefully acknowledge to whom we owe the firſt Revelation of this important Truth. The Syſtem of the ancient Phyſicians is, "That the Blood "paſſes from the Heart as well by the Veins as "the Arteries, the nutritious Part of it by the "former, and the more ſpirituous by the latter; "but that nothing returns to the Heart more "than a Chyle, abſorbed by the meſenteric "Veins, and by them conveyed to the Liver, "where it is firſt concocted and puts on the "Nature and Colour of Blood, before it goes "to the Heart."

[2] *Hippocrates* has had the Honour given him of knowing the Circulation, firſt by *Riolan*, and then by *Drelincourt* and others; but it is certain, that if he underſtood the Blood's Motion, he has expreſſed himſelf ſo unintelligibly about it, that his acuteſt Interpreter, *Galen*, did not thence ſo much as ſuſpect that the Blood had a circulating Courſe. But we are well aſſured, that the firſt Author who taught "that the Blood of the Vena Cava did "not paſs thro' the Septum Cordis into the left "Ventricle, but that it arrived thither by a long "Courſe thro' the Artery and Vein of the Lungs," was one *Michael Servetus*, a *Spaniſh* Phyſician, in his very ſcarce Book, *De Erroribus Trinitatis*, publiſh'd at *Baſil* in the Year 1531. The ſame thing was ſoon after propoſed by *Columbus* in a manner ſo much alike, that one of them ſeems to have taken it from the other. After theſe, *Caeſalpinus* had much the ſame Notion, and alſo imagined that the Veins did not convey the Blood from, but to the Heart. All theſe ſeem to have had a diſtant View of the Blood's true Courſe, but in

part

Auricle from the Subſtance of the Heart by the coronary Veins; which laſt is doubtleſs diſcharged with a conſiderable Force, and render'd very fluid by the muſcular Contraction.

1 The Blood of a healthy Perſon coagulates into a ſolid Cake barely by ſtanding ſtill a little while; but when the Auricles of the Heart contract, the Blood in the adjacent Veins and their Sinus's muſt of Neceſſity ſtop, and wait till the Auricles are relaxed, and till more Blood ſucceeds from the Veins: The Blood of the large Veins is therefore in the greateſt Danger of coagulating, if that was not prevented by a plentiful Dilution with Lymph; and by the Concuſſion of the Auricles, which having a rough Surface, do by their muſcular Columnæ attenuate the Blood, and blend it with the Chyle.

2 It is not probable that all the Blood which enters from the Sinus's into the Ventricles of the Heart, is firſt retained in and ſent thither by the Auricles; for in the left Ventricle there is not room enough to hold all the Blood which comes from the Lungs; and therefore it is probable, that when the Auricle ſends its Blood in the Ventricle, ſome Part of the Blood will then ſlip from the Sinus directly into the Ventricle, without being at all retained in the Auricle. The Quantity of Blood which thus ſlips thro' the Auricle from the venous Sinus into the right Venticle, does not ſeem to be more than a tenth Part of what the Auricle will contain, becauſe the Proportion of the Sinus to the Ventricle is not larger.

3 All the Blood of the Heart itſelf is diſcharged by the coronary Veins, either into the Sinus of the Cava, the right Auricle, or elſe the right Ventricle. But this Blood is more agitated, warm and fluid than that of any other Part; and there-

fore

fore it may render the other Blood, with which it mixes in the Auricle, more thin and fluid than it otherwiſe would be.

§. 164. But what Alteration or Impreſſion is made on the Blood and Chyle by the Action of the Heart, can be underſtood only from the Structure of that Organ and the Nature of the Blood; in our Enquiry after which, we ought to rely only upon ſolid Experiments, ſuch as we ſhall preſently mention, ſince the Subject has afforded much Controverſy, and ſeveral Hypotheſes [1].

[1] The Opinion of the Ancients was, that the Blood paſſed from the Liver into the right Ventricle of the Heart; and that from thence it went in part into the pulmonary Artery to nouriſh the Lungs, and that the other Part tranſuded thro' the muſcular Septum of the Heart into the left Ventricle, where, mixing with the vital Spirit from the Lungs, it became arterial Blood. And in the laſt Century the Chemiſts and Followers of *Sylvius de la Boe* ſuppoſed the Blood in the Heart of an alkaline Nature, and that it fermented with the other Blood, which abounded with an acid Chyle and pancreatic Juice. *Carteſius* ſuppoſed the Blood to enter the Heart by a Drop at a time, which by intenſe Heat ſo rarified as to diſtend the Heart, and then ran out boiling into the Lungs to be cooled.

§. 165. The Blood contained in the right Ventricle of the Heart of a faſting Animal does not taſte either *alkaline* [1] or *acid* [2], but *brackiſh* [3], like that of Sea-ſalt, or Sal-ammoniacum.

That

nected to their fleshy Columnæ on each Side, that they cannot be quite closely approximated even with the Sides of the right Ventricle; the Valves are therefore thus pressed by the Blood towards the right Auricle, till they meet close together, and by occluding the Passage, *entirely prevent its Return:* For the Columnæ of the Valves will not permit them to be pressed farther back than to meet, and the venal Blood returning from the whole Body also supports them on the other Side; so that by these means the Contraction of the Heart, tho' strong, cannot urge the tricuspid Valves too far back towards the venous Sinus [2].

[1] For the stronger the Blood is urged towards the Cava by the Contraction of the right Ventricle, the farther are the tricuspid Valves thrust out, and more closely approximated by the same Means; and when the Valves have had their greatest Distention, which is but small, except the pulmonary Artery be obstructed, this last is then immediately open'd, and a Passage thereby made for the Blood to enter into the Lungs. In the mean time, while the right Ventricle is contracting, the venal Blood is collected in the right Sinus and Auricle against its Relaxation, when, depressing the Valves, it passes into the right Ventricle by Pressure, its own Weight and the Force of the succeeding Blood in the Veins.

[2] When the Heart is relax'd and receives the Blood, its muscular Flesh at that Instant appears intensely red; because at that Time all its coronary Arteries and Veins are turgid with Blood, drove into them by the Contraction of the Aorta: But when the Heart is in its Systole or Contraction, the

the Blood before received into the Veſſels of its muſcular Subſtance is then expreſſed and diſcharged by the larger coronary Veins, which open into its right Sinus and Auricle; and Part of the Blood is alſo expreſſed thro' the exhaling Veins which open in every Part of the right Ventricle, by which means the Heart at that Inſtant becomes pale and bloodleſs. Nor is it improbable, that the Blood in the larger Trunks of the coronary Arteries returns again at that Time into the Aorta by their Orifices which ariſe from thence. In Fiſh, this alternate Change of Paleneſs and Redneſs in the Heart is very conſpicuous, ſince they have but one Sinus, Auricle and Ventricle, one Vein and one Artery. In them the venous Sinus firſt becomes turgid, then the Ventricle, and then the Artery, which is turgid in its Repletion; and at the ſame Inſtant the Sinus alſo becomes turgid and red.

§. 152. By this Contraction of the right Ventricle, (§. 151.) the ſame Blood is alſo forced up againſt the three ſemilunar Valves, attached to the Margin of the other Aperture of this Ventricle, in the Entrance of the pulmonary Artery; and by preſſing thoſe Valves againſt the Sides of their Artery, forces itſelf a Paſſage into that Veſſel only.

§. 153. But ſuch is the Structure and Connection of theſe Valves, (§. 152.) that it is evident they are fill'd out and meet together, by the Reaction of the Blood in the pulmonary Artery towards the right Ventricle, ſo as to intercept its Return, ſince they cloſe more exactly, as the Blood endeavours to return more forcibly. But at the ſame Time that theſe Valves are

ſhut

ſhut and diſtended by the Blood in the pulmonary Artery, they are alſo then ſupported on the other Side by the Blood drove out of the venous Sinus into the Cavity of the Ventricle; by which means they are preſerved from being broke or over-ſtrained by the Repulſe of the Blood urged by the Contraction of the pulmonary Artery.

§. 154. All this (§. 151 to 154.) is proved not only from the Structure of the Parts, but alſo by Obſervation in living Diſſections, with Arteriotomy and Injections.

§. 155. It therefore follows from hence, that the venal Blood coming from all Parts of the Body, (§. 146.) continually paſſes with a quick and ſtrong Motion out of the venous Sinus, thro' the right Auricle and Ventricle, into the pulmonary Artery alone.

§. 156. In the next Place the Blood paſſes from the Artery into the pulmonary Vein, and left venous Sinus, formed by the meeting of the four large Branches of that Veſſel; by the muſcular Fabric of which Sinus the Blood is thence preſſed into the relaxed Cavity of the left Auricle, which is much leſs than the right, tho' it has the ſame Structure and Poſition. From the Auricle it paſſes (§. 148.) into the left Ventricle, when relaxed; into which it may readily enter by its two *mitral Valves* having the ſame Mechaniſm as the tricuſpids before, (§. 149, 150.) which alſo prevent it from returning back the ſame Way, (§. 151.)

As

As the left Ventricle contracts with a much greater Force than the right, and exerts proportionally a ſtronger Preſſure againſt the Valves to ſhut them when it protrudes the Blood into the Aorta, there was here no Need of three Valves at the Entrance of the pulmonary Vein, two being ſufficient, which have a narrow Opening into the left Ventricle, like a Slit; to cloſe which with the greater Reſiſtance, when the Heart contracts, the membranous Sides of the Valves are wrapped over each other, and form as it were a double Partition.

§. 157. The Blood protruded into the Aorta by the right Ventricle, is determin'd ſtrait forwards in that Veſſel by the *three ſemilunar Valves* [1] placed at its Entrance, (as §. 152, 153, 154.) and this more eſpecially when the Artery contracts, at which Time the Blood reacting on the Valves, cloſes them very exactly. But what has been hitherto ſaid, relates to the Courſe of the Blood in Adults, and thoſe of our Species who breathe in the uſual manner: As to its Circulation in the Fœtus, ſee §. 680, *& ſeq.*

[1] Which have been alſo denominated Sigmoide, from their Reſemblance to the old Sigma of the *Greeks*, which was ſhaped like our Roman C.

§. 158. Hence it is evident, that all the Blood of the pulmonary Artery paſſes by the Vein into the left venous Sinus, thence into the left Auricle and Ventricle, and thence into the Aorta; and thus continually, with a ſtrong and ſwift Motion.

At

At that Inſtant when the right Ventricle of the Heart is contracted, it does not admit any of the Blood from the Cava; it muſt then be accumulated there, ſo as to fill the right Sinus and Auricle, as it alſo muſt in the left Sinus and Auricle: But when the Ventricles of the Heart are relaxed by the Depletion of their coronary Arteries, and Compreſſure of their Nerves, the contractile Force of the venous Sinus's which they continually exert, will then overcome the Reſiſtance of the Heart, which as a relaxed Muſcle will be no more than its Weight; and thus the Ventricles will be filled with the Blood that was till then collecting in the Sinus's. At the ſame Inſtant of Time that the Ventricles are thus filling, the coronary Arteries will be alſo filled by the Aorta; and when the Aorta and pulmonary Artery are contracted, or at reſt, the cardiac Nerves will be then free from Preſſure, the two Cauſes of Motion in the Heart will be thus renew'd, and its former Contraction muſt follow. Hence the perpetual Motion of the Heart.

§. 159. This Motion or Courſe of the Blood before deſcribed, may be diſtinctly obſerved *in living Diſſections*[1], and is then attended with the following Phænomena.

1. Both the venous Sinus's are filled, become turgid and red at one and the ſame time; and ſo are both the Auricles.

2. Both the Auricles become flaccid at the ſame Inſtant, and ſo do alſo the two venous Sinus's.

3. In the very Moment that the Auricles become flaccid, they are then fill'd with

Blood, by the Impulſe of that in the Veins, together with the muſcular or contractile Force of the venous Sinus's.

4. At the very Inſtant when the Auricles are thus fill'd, both the Ventricles of the Heart contract themſelves at one and the ſame Time; in which Action they become pale, and diſcharge their contained Blood into the two large Arteries, which are thus filled and dilated.

5. The Moment after this Conſtriction of the two Ventricles, they become empty and flaccid, are *elongated* [2] and enlarged, and appear red.

6. The laſt Appearances are no ſooner obſerved, but the two Auricles and muſcular venous Sinus's contract with a muſcular Force; by which they diſcharge their contained *Blood* [3] into the empty Ventricles of the Heart, and in this Action the Auricles look pale.

7. In the mean time the venous Sinus's will be again filled, and then the Auricles, as we firſt obſerved: And in this Order will all the forementioned Appearances return again, and be continued in the ſame Series, till the languiſhing Animal is near dead [4].

8. But when Death approaches, the Auricles and venous Sinus's beat ſeveral times to one Contraction of the Ventricles [5]. At length, the left Ventricle firſt ceaſes to move, and then its Auricle; afterwards the right Ventricle is ſtill, and laſt of all the right Auricle. The Animal is now dead, after which

we

we find the left Ventricle empty, but the right Ventricle always full of Blood.

[1] Theſe Appearances are beſt remarked in the Diſſection of young Whelps or Kitlins, ſoon after their Birth; becauſe theſe live much longer without breathing, after the Thorax and Pericardium have been open'd.

[2] Injecting the Heart with warm Water fills its Ventricles, and renders them longer; but upon preſſing the Apex of it towards the Baſis, the Water paſſes out into the Arteries.

[3] This Force is equal to that with which the Heart impells the Blood into the Arteries; otherwiſe, if the Force was but little leſs, the Blood would return more ſlowly to the Heart, which would conſequently ſend it more ſlowly into the Arteries; and this ſmall Difference increaſing every Minute, there would at laſt be no Blood impell'd into the Heart, which would therefore ceaſe to move.

[4] Upon wounding the carotid Artery of a living Dog, the Blood ſpouts forth like the Jet of a Fountain; but growing gradually weaker, it at length ſtarts out only at Intervals, till at laſt the Flux totally ceaſes. In this State the Heart of the expiring Animal is found ſtill and contracted, yet the Auricles continue to beat or contract weakly and at longer Intervals, till at length the Ventricles being filled, the Heart with a ſudden Start contracts itſelf again; but this Syſtole being over, the Heart remains flaccid and without Motion for a Minute or two, and as long an Interval paſſes before the Animal breathes: Thus the Heart continues longer and longer at reſt each Time, till there is Blood enough accumulated in the Sinus's and Auricles to overcome the Reſiſt-

ance of the Ventricles. At length the muſcular Force of the right Ventricle becomes too weak to overcome the Reſiſtance of the Lungs, and therefore contracts no more, which makes the Death of the Animal. But even after this the Blood continues to move towards the Heart in the Veins, being propelled by the Contraction of the Veſſels aſſiſted by the Cold, which follows Death. At laſt the right Ventricle being dead, the Auricle only palpitates; and when that is ſtill, there only remains a ſmall Motion for a Time in the Cava near the Heart.

5 It has been long ago obſerved, that the Motion of the Auricles in the Heart remains after that of the Ventricles; and the Fact is alſo demonſtrable to the Eye by opening the Thorax of a living Animal. But what is more extraordinary, both the Auricles and Ventricles of the Heart may be reſtored by Art to their former Contractions even after they have ceaſed to move, or when the Animal is really dead. Thus *Peyerus* and *Wepfer* demonſtrate, that by blowing into the thoracic Duct, or into the Vena Cava ſo as to urge forward the Blood, the Heart of the dead Animal will by that means renew its Contractions; as it alſo will barely by preſſing hard on the Thorax, tho' the Spectators might imagine this to have the contrary Effect. This ſeems to have been the Caſe with the great *Veſalius*, who was baniſhed for opening a *Spaniſh* Nobleman before the Heart had done moving. So that if the Heart deſerves the Title of *ultimum moriens*, the right Ventricle and Auricle are the moſt deſerving of it, as they move longer than the left; but the Cava laſt of all. Nor is it at all ſtrange that the right Ventricle, which is the weakeſt, ſhould move longer than the left; for Reſpiration ceaſing, the

part only; ſo that as they did not underſtand or explain the whole, and confirm it by ſufficient Proofs, the great *Harvey* has ſtill a juſt Title to the Invention or Diſcovery: For by an Inventor we underſtand one, who is not only acquainted with the Thing he propoſes, but who alſo demonſtrates or explains the ſame, ſo that all Men of Learning may be convinced of and comprehend it; but this was firſt done by Dr. *Harvey* only, who has ſupported his Syſtem with innumerable Experiments, and has by that means given more Light into all the Branches of Phyſic than we have ever receiv'd from any other anatomical Diſcovery. We are even bound to acknowledge the high Merits of this great Man, to whom we all owe a profound Veneration; becauſe it is upon his Syſtem only, that we can obtain any juſt Notions either in the Theory or Practice of Phyſic, which have by this means been purged from Fiction, and founded on the true Baſis, which is equal to the Dignity of the Profeſſion.

3 In 1656, *Wren* and *Lower* firſt injected Liquors into the Veins of Animals; ſince which Time we have had various medicinal Liquors injected into the circulating Blood of Men, which have produced the very ſame Effects throughout all the Veſſels of the Body, as if a larger Doſe of the ſame Medicine had been taken inwardly,

4 In 1658, Dr. *Henſhaw* diſcover'd a Method of transfuſing the arterial Blood of one Animal into the Veins of another; which Experiment was afterwards improv'd and publiſh'd by Dr. *Lower*, (*de Corde*) *Ann.* 1665. The Blood of the emittent Animal being hereby exhauſted, it expires, while the Recipient continues alive and well. To do this, let two Dogs be tied down near each other upon the ſame Table; then denudate and tye the

carotid Artery of one, and the crural Vein of the other, and after making an Inciſion in the Carotid betwixt the Heart and Ligature, inſert a Tube, whoſe other End is to paſs by an Inciſion into the crural Vein of the other; and thus the Blood will paſs into the Veins of the laſt Dog, till the firſt expires. This Experiment ſeems to have been firſt hinted by *Libavius*; and tho' Dr. *Lower* was undoubtedly before-hand with Monſ. *Denis* in the Trial of it on Brutes, yet the *French* firſt tried the Transfuſion on Men. The Experiment was ſoon received with great Applauſe both thro' *France* and *England*, and great Things were expected from it in the Cure of Diſeaſes, and the Recovery of Youth, ſince they cou'd now convey the Blood of a ſound and young Animal into a Man that was old or diſeaſed, and by that means procure the Longevity talked of by the Alchemiſts from their Elixir or Stone. But in a little Time all theſe Expectations diſappear'd, and the Experiment was prohibited to be made on Men by the public Law. For a *Swediſh* Nobleman being given over by his Phyſicians in an ardent Fever, one of them was willing to take the Advice of *Hippocrates*, to make Trial of an uncertain Remedy in a deſperate Caſe. Accordingly an Exchange is made, by Transfuſion, of a few Ounces of the Patient's Blood for a Quantity of that from a ſound Animal; the Experiment ſucceeds, and the Patient is much better, inſomuch that Transfuſion becomes eſteem'd and admir'd by the whole Court of *France*; it muſt therefore be repeated, ſince the Patient's Blood does not yet move ſlow enough: But very unfortunately the noble Patient expires even in the Experiment, and becomes a Victim to the Curioſity of Phyſicians. Hereupon Transfuſion comes into Diſgrace, is prohibited by Parliament, and meets with

with ſuch univerſal Neglect, that at preſent we hear not the leaſt Talk of it.

5 The Blood's Circulation was diſcover'd to the Eye by the Microſcope in 1661, by *Malpighi* and *Lewenhoec*. The latter ſaw it paſs out of the ſmalleſt Arteries into the continuous Veins. But the old Gentleman was ſo infatuated or miſled by his Experiment, that, contrary to every body's Opinion, he thought the Veins had a Pulſation, and that the Arteries had none. This Error ſeems to have aroſe from the retrogade Courſe of the Blood in many of the evaneſcent Arteries, as ſome of their Anaſtomoſes contract and are obſtructed in the dying Animal, ſo that the Blood moving the ſame Way both in Arteries and Veins, has made me ſometimes look ſeven or eight Minutes without being able to diſtinguiſh one from the other.

§. 161. It alſo follows that the Chyle, (§. 126.) being continually preſſed in a ſmall Quantity thro' the thoracic Duct (§. 125.) will ſo far open the Valves in the ſubclavian Vein, (§. 124.) (which are always kept ſhut by the oppoſite preſſure of the Blood) as to admit a Quantity of Chyle, which by its Weight is able to overcome the Reſiſtance of the Blood in the ſame Vein, thro' which it will deſcend, together with the Blood, into the Cava and its Sinus, and thence into the right Auricle and Ventricle.

§. 162. The Chyle being plentifully diluted with the returning Lymph, and thus continually mixing in a ſmall Quantity with the Blood, and that running together from the Veins in oppoſite

poſite Directions [1], does not only preſerve them from coagulating in the Cava, but makes the firſt Mixture of the Blood and Chyle there.

[1] The right and left ſubclavian Vein open into the Cava in oppoſite Directions; ſo that the Blood of the right Subclavian, which has none of the Chyle, mixes with the oppoſite Stream of the left Subclavian, charged with the Chyle. About the ſame Part the jugular Vein alſo opens after it has deſcended perpendicularly, and conveys the Blood diluted with all the Lymph ſeparated in the Parts of the Head, and with the moiſt Vapours which part the dura Mater and pia Mater from each other, and the latter from the Brain itſelf. Thus the Blood meeting from the Veins in oppoſite Directions occaſions an intimate Mixture. And in the way, before the Blood of the Vena cava paſſes to the Heart, it meets with that of the Vena azygos, which aſcends thro' the whole Thorax; from all which, and many more Veins of different Courſes, the ſuperior Trunk of the Cava receives its Blood before it paſſes to the right Auricle and Ventricle of the Heart.

§. 163. The Blood and Chyle being in the next place drove into the furrow'd Cavity of the Auricle, is there, by its forcible Contraction, and the oppoſite Concuſſions of its muſcular Columnæ on every Side, ſtill more intimately mixed, divided and render'd *Fluid* [1], alſo the Mixture and Fluidity is render'd ſtill more perfect by the Occurſion of the little Blood that *ſlips thro' the Auricle* [2], together with the Blood returned into the Cavity of the Auricle

[1] That healthy Blood is free from any alkaline Acrimony, may appear not only from its having no ſuch Taſte, but alſo from its giving not the leaſt Pain to wounded Parts, nor even to the Eye itſelf, if dropt into it; nor does it manifeſt any Fermentation with Acids, nor turn the violet-colour'd Tincture of Flowers green as alkaline Salts do.

[2] An acid Acrimony is ſtill infinitely more remote from the Blood, ſince its natural Tendence is to Putrefaction, after Reſt.

[3] This Brackiſhneſs is in the Blood of People who eat much Sea-ſalt; but in Brutes which are not domeſtic, it is almoſt inſipid.

§. 166. If the Blood be mix'd either with Acids or Alkalies, it does not afford any apparent Motion of Fermentation, but it thereby receives ſome Change in its *Colour* [1] and Degree of Fluidity. Indeed Oil of Vitriol, which is diſtill'd by the moſt intenſe Fire, and highly rectified, makes an Efferveſcence with the Blood, as it does with all other Liquors, eſpecially the oily.

[1] With *Oleum Tartari per deliquium* the Blood becomes turbid, and of a fiery Colour; with *Sp. Salis ammoniaci* it becomes thin and fluid, and of a florid Colour; with ſeveral Sorts of Vinegar it preſerves its Fluidity; but with Spirit of Nitre and other mineral Acids, it coagulates; yet it does not produce any Ebullition with either of theſe; and tho' it will make an Ebullition with highly rectified Oil of Vitriol, 'tis only from the Water in its Compoſition, which, whether alone or in any other Liquor, is moſt powerfully attracted by that

that ſtrong Acid. Some tell us, that as both an Acid and an Alkali is obtained by diſtilling the Blood, therefore both of them muſt be naturally in its Compoſition; whereas they are both in reality the Produce of the Fire. Others endeavour to evade our Argument by ſaying, that the lixivial Salts in the Blood are naturally ſuch as will not ferment with an Acid: If ſo, how do they appear to be lixivial? for we are no otherways aſſured that an alkaline Salt exiſts in any Body, but by the Phænomena or Effects it produces therein; and when thoſe Effects are not to be found, we muſt reaſonably conclude the Cauſe or Alkali to be abſent.

§. 167. The Blood which ſtarts out from a Wound in the pulmonary Artery, being received into a Veſſel, does not afford any Signs of an inteſtine Ebullition or Effervescence, but yields a ſharp and *ill-ſmelling* [1] Vapour; and after ſtanding in the Cold, it congeals, and then ſeparates into two Subſtances, one of which is more compact and ſolid than the Maſs of Blood itſelf, and the other is ſerous and more fluid.

[1] This is a rank Smell, coming betwixt the Odour of Sweat and Urine, and which is hardly perceptible in the Blood of an Ox.

§. 168. If the Apex of the Heart in a living Animal be cut off, and you then turn it upwards, you will perceive the Blood to be drove by the Auricle into the right Ventricle, when the firſt contracts; but this without any Ebul-

Ebullition or Fermentation, as you will more distinctly perceive towards the Death of the Animal. And all these Phænomena (§. 165 to 169.) are also true in the Blood of the left Ventricle.

§. 169. If a *Thermometer* [1] be thrust into the Heart of a living Animal, it does not discover that the Blood has a greater Heat there than in the other Viscera. At which we need not wonder; for if, from the Difference of Velocity and Attrition, the venal Blood returns something cooler than the arterial, as they both meet in the Heart, they will be there of the same Temperature.

[1] Several Experiments of this Nature were made so early as 1666 by *Malpighi*, *Borelli*, and others. They opened both the Heart and the Limbs of the same Dog, and upon inserting a Thermometer into the Ventricle and into the crural Artery, they found that both the Instruments indicated the same Degree of Heat. Those who embraced the Hypothesis of the Ancients, objected, that as the Heart was universally allow'd to be the Fountain of Heat, they cou'd not see why the Blood in that shou'd not be hotter than in the Limbs. It is indeed certain, that as the Blood moves slower, and with less Attrition in the Veins than the Arteries, it wou'd be cooler in the former than in the latter, if they did not take the same Course, and run close to each other. And as the greatest Share of Motion and Attrition is communicated to the Blood by the Heart and Lungs, it wou'd be proportionably hotter in those than in the other Viscera, if it was not to communicate Part of its Heat to the colder Air in the Lungs;

Lungs; which Communication of Heat from the pulmonary Blood to the Air is very readily made, both from the Thinneſs of the Membrane which parts 'em, being ten times thinner than writing Paper, and from its vaſt Extent or Surface within the Lungs, being computed more than the Surface of the whole Body. But as the external Air is always colder than the Blood, it will by Contact with the Lungs become warm; ſo that in the Winter time it may be blowed out warm, agreeable to the Fable of the Satyr. But as much Warmth as the Air gains in the Lungs, ſo much muſt the Blood loſe there; upon which account, in a hot Air we pant, or breathe more frequently; that by oftner changing the warm Air, which does not take off ſo much of the Heat of our Blood, we may bring it to the ſame Temperature, as we might by fewer Reſpirations of a colder Air.

§. 170. The Taſte of the Chyle in the thoracic Duct is generally that of *Sea-ſalt* [1], or the Flavour which was predominant in the *Aliments* [2].

[1] *i. e.* When it has not the ſweet or milky Taſte at §. 127.

[2] Thus the Smell and Taſte of Onions, Garlic, Aſparagus, Turpentine, *&c.* may be not only perceived in the Chyle, but alſo in the Nurſe's Milk, in the Sweat, Urine, *&c.* even the Colour and medicinal Qualities of ſome Things are alſo extended in the ſame Manner, as Rhubarb, the Machine le apple, *&c.* and even Madder tinges the very Bones. See *Phil. Tranſ.* N°. 442, and 443. Hence, if ever there be any Acid or Alkali in the Blood, 'tis that of the Chyle or Aliments not yet digeſted, and will be always too mild to yield any Taſte or Fermentation.

§. 171.

§. 171. The ſame Chyle taken from the Duct, and mixed with Salts of an oppoſite Nature, hardly ever makes the leaſt Ebullition.

§. 172. If the ſame Chyle be received into a clean Veſſel, it is never obſerved to have any Motion of Fermentation or Ebullition.

§. 173. Nor is any ſuch Motion apparent in it, whilſt remaining in the thoracic Duct.

If you open the Thorax of a Dog, and cloſe the wounded Veſſels with Vitriol, you may then plainly obſerve with your Eye, that the Chyle paſſes thro' the thoracic Duct into the Blood of the Subclavian without any manner of Froth, Luctus, or Ebullition either in the Duct or Vein.

§. 174. Nor does the Chyle make any Ebullition or Fermentation during its Stay in the thoracic Duct, nor when it is drove from thence into the Subclavian, nor when mixed with the Blood in the Cava, or the Auricle and Ventricle of the Heart.

§. 175. Nor does it appear to make any Ebullition, if you intercept its Courſe by making a Ligature in the Subclavian betwixt the Valves and the Cava.

§. 176. And laſtly, as the Chyle is mixed in its Courſe with a vaſt Quantity of Lymph from the conglobate Glands (§. 105.), which is ſeparated from the arterial Blood, and poured either into the Chyle itſelf, or into the venal Blood with which it mixes, it will from hence follow, that the Chyle muſt be nearly

homogeneous, or of the ſame Nature with the Blood itſelf, with which it muſt therefore unite ſmoothly, and without any Luctus, as we are alſo convinced it does by Experiments.

Sylvius de le Boe, to ſupport his Syſtem of Fermentation betwixt the Blood and Chyle, taught, that tho' the Blood itſelf was not acid, yet the Lymph thence ſeparated became ſo by ſtagnating in the conglobate Glands, and mixing there with an acid Spirit ſecerned from the Blood. But, on the contrary, (1.) the Lymph, when left to itſelf, always turns putrid or alkaline, and not acid, as it ought to do on his Principles: And, (2.) the Chemiſts have never yet produced an Inſtance of an alkaline Subſtance turning acid, which is a Change the leaſt of all to be expected from Stagnation or Reſt.

§. 177. It therefore follows, that there is no *Fermentation* [1], *Effervescence* [2], or *Ebullition* [3] produced in the Heart, either from the Organ itſelf, or the mixed Fluid which enters it; and therefore we cannot expect, nor find any of the *Effects* [4] of ſuch Motions.

[1] Fermentation is that apparent inteſtine Motion in the Parts of Liquors at Reſt, which generates many Air-Bubbles, and produces an acid and inflammable Spirit. Thus new Wort made without Hops will ferment to ſuch a Degree as to run all into Froth, which if confined will often burſt the including Veſſel, with ſo much Violence as makes their Parts fly to an incredible Diſtance. But the Blood does not come into the Claſs of vegetable Liquors, to which this Operation is reſtrained, nor

nor is there a Poſſibility for it to fervent. Nor does it ever generate Air, even by its moſt violent Commotions in ardent Fevers, ſo as to burſt its including Veſſels.

[2] Effervescence is a Name we give to the Noiſe, Rarefaction, and aſcending Air-bubbles, produced by mixing two Liquors before at Reſt. That there is no ſuch Commotion in the Blood we are convinc'd, (1.) from the Abſence of the Cauſes, ſince it never contains oppoſite Salts (acid and alkaline) of that Strength or Quantity ſufficient to make any ſenſible Luctus. (2.) From the Abſence of the Effects, ſince we cou'd never obſerve by any Experiment, ſuch a Motion in the Blood either within or out of its Veſſels. It has indeed been aſſerted by *Homberg*, and ſome other *French* Gentlemen, that there may be a latent Effervescence in the Blood, not ſenſible to the Eye; and for an Inſtance, that ſuch a latent Effervescence is poſſible, they bring a Mixture of Spirit of Nitre with Cantharides, in which we obſerve no Luctus while the Air has a free Admiſſion; but ſo ſoon as the Bottle is corked, a Commotion ariſes in the Mixture, by which the Cork is drove out with a conſiderable Force, and that even if the Mixture has ſtood by for ſome Years. In Anſwer to this, we readily grant that there may be ſuch a Luctus or inteſtine Motion in the Parts of the Blood as is not ſenſible, eſpecially if it ſtagnates; but then it ought not to be termed Fermentation or Effervescence, which is a ſenſible Phænomenon; nor do we allow it to be productive of the ſame Effects.

[3] This is ſuch a Motion in Liquors as cauſes them to boil up ſtrongly, and diſcharge great Bubbles of Air. Such an Appearance we obſerve in Water heated, ſo as to raiſe the Thermometer above 180 Degrees. That there is no ſuch Ebul-

lition of the Blood in the Heart, we prove by Experiment: For upon opening the Thorax of a Dog, and inſerting your Finger by an Inciſion into the Heart, you will feel a Conſtriction in its Syſtole, but no Rarefaction or Ebullition; beſides, as there are no productive Cauſes of ſuch an Ebullition in the Heart, and as its Effects would be ſo highly pernicious, 'tis reaſonable there ſhould be none. If you are pleaſed to aſſert a latent or inſenſible Ebullition in the Heart, we ſhall not contradict, ſince our Concern is only with ſenſible Phænomena, productive of ſenſible Effects.

[4] As the lateſt Aſſerters of theſe hypothetical Commotions in the Blood, have been forced to own them latent or occult; ſo their Effects are equally imperceptible with the Cauſes, and have only their Exiſtence in a prejudiced Imagination.

§. 178. Nor does the *Warmth* [1] of the Heart cauſe any Change in the Nature and Motion of the Blood, nor expel it from thence.

[1] Since the Heat of the Heart is no greater than that of the other Arteries (§. 169.) Heat cannot be the Cauſe which forces the Blood out of the Heart into the Arteries, according to the Theory of *Carteſius*.

§. 179. Nor is there any kind of Ferment in the Heart.

Of this Opinion was *Vieuſſens*, who lately revived the *Carteſian* Hypotheſis, and added new Arguments to it. 'Tis ſcarce credible, how a Man in his Senſes ſhould imagine a Fire or Ferment to be contained in the Cavity of a tender Muſcle, as

is

is the Heart. Who can believe that in the 7200dth Part of an Hour is ſeparated a liquid Ferment ſo very different from its Origin in the Blood itſelf, that in the ſame Inſtant of Time it can heat the Blood, and change its Nature; or who can believe that ſuch a Ferment ſhould conſtantly reſide in the Heart without being waſhed out, when no leſs than 600 medical Pounds of Blood paſs thro' that Organ in the ſpace of an Hour? But this otherwiſe induſtrious Anatomiſt ſeems to have been led into the Miſtake by an Experiment which he thought argued for the Hypotheſis, *viz.* That upon injecting a coloured Liquor into the coronary Arteries, it paſſed through into the right Auricle and Ventricle of the Heart; hence he rightly judged that the Blood of thoſe Arteries paſſed very ſwiftly the ſame way, and by its Velocity acquired more Heat; but then he was wrong in thinking that increaſed Heat ſufficient to rarify and warm all the other venal Blood. We grant, that the Blood of the coronary Arteries does (by that increaſed Velocity and Attrition with which it paſſes thro' the Subſtance of the Heart, in its muſcular Contraction) acquire a greater Degree of Heat, by which it may render the venal Blood with which it mixes ſomewhat more warm and fluid; but then this Heat can never be ſufficient to propel the Blood, and overcome the Reſiſtance of all the Arteries, agreeable to the Syſtem of *Carteſius*; nor yet can it produce that Difference which is obſervable betwixt the arterial and venal Blood.

§. 180. The Cauſe therefore which propels the Blood out of the Heart into the Arteries, and from the Veins into the Heart again, does not reſide in the Blood.

The Syſtem of *Carteſius* and his Followers is, "that the Blood being rarified by Heat, ruſhes "out of the Heart, and dilates the Entrance of "the Artery, in the ſame manner as when Milk "boils up on the Fire, or as bottled Ale flies up "in the Air as ſoon as you draw out the Cork, "in which manner it will aſcend even through a "Tube, if you inſert one in the Neck of the "Bottle; ſo that the Heart may be compared to "the Bottle, and the Artery to the Tube, *&c.*" But as this Error has been long ago refuted, we ſhall only anſwer in brief, (1.) That the Blood in the Heart does neither ferment, efferveſce, nor make any Ebullition. (2.) That it is not expell'd from the Heart in its Dilatation, but in its Contraction or Syſtole. (3.) That if the Blood had any ſuch Motion, it muſt be obſervable to the Eye, and afford a deal of Froth, neither of which can be demonſtrated.

§. 181. But this Cauſe (§. 180.) muſt then be ſought for in that which immediately receives and retains the Blood, that is, in the Heart itſelf; in which, in order to demonſtrate it, we are firſt to make an acute Survey of the Subſtance, Structure, Motion and Force of that Muſcle.

Of

Of the Structure and Action of the Heart.

§. 182. THE Heart, being every way *at Liberty* [1] for Motion, in a *large* [2] membranous Receptacle, termed *Pericardium* [3], (which is accurately closed on all Sides, and firmly attached to the Throat, Sternum, Spine, and *Diaphragm* [4], either immediately, or by the Vessels and ligamentary Processes it sends forth) and being also moisten'd with a lubricating *lymphatic Liquor* [5], expressed from the small Arteries in the Superficies of the Heart itself and its Auricles, is likewise sustained *pendulous* [6] by its four great Blood-vessels, which its Pericardium very strictly embraces. Its Position is lengthways, in an oblique and almost *horizontal Posture* [7], with its flat Side on the Diaphragm; to the tendinous or middle Part of which it is firmly connected by the Vena Cava and right venous Sinus below; and above, in the Thorax, it is connected within the Duplicature of the *Mediastinum* [8], and lodged betwixt the soft Lobes of the Lungs; by all which means it avoids too great a *Pressure* [9] on any Side, and is most commodiously adapted to receive the Blood from, and propel it into all Parts of the Body [10].

[1] This is one of the principal Differences betwixt the Heart and other Muſcles, that it is not, like them, connected to any Bones, nor has any fix'd Point to act upon; for the very Weight which it moves, *i. e.* the Blood, is the Fulcrum whereon it acts, and which it diſcharges, by an unequal Preſſure, where it meets the leaſt Reſiſtance, *i. e.* into the Arteries. Beſides, if the Heart impinged againſt any hard Body in its perpetual Motion, as it has been ſometimes obſerved to do, in thoſe who have had their Thorax too much contracted, the Conſequence muſt be a Train of Diſeaſes, violent Palpitations, *&c.* which are thus avoided.

[2] So large that it will contain double the Bulk of the Heart, as you may be convinced by the Experiment of filling the Pericardium with as much Water as it will contain without Danger of burſting; and then, if that Water be diſcharged, and the Heart taken out, the Pericardium will hold twice as much as before; which Space was the more neceſſary in the Pericardium, that the Heart might move freely in it.

[3] We know not of any Animal whoſe Heart is not defended with this Capſule; even Fiſh, who have this Organ placed in their Head, are furniſhed with a thick, fleſhy, and ſometimes cartilaginous Integument, which ſerves the Heart as a Pericardium. But a ligamentary or membranous Receptacle is not peculiar to the Heart alone; for every Muſcle and Tendon has its Capſule, in which it moves, is lubricated, and is more or leſs at Liberty according to the Amplitude of its Motion.

[4] In Brutes we find only the Apex of the Pericardium attach'd to the Diaphragm; but in the Ape or Monkey-kind its Connection a little more reſembles that of the human Body, in which it lies flat,

flat, with its Apex towards the right Side, and its Basis towards the left; its broadest Side being so intimately attached to the tendinous Part of the Diaphragm, as to be inseparable without Laceration, by which means it sustains that broad Muscle, with the several Viscera connected pendulous to it; so that the Diaphragm cannot by their Weight be drawn down too low in the Abdomen, in our erect Posture.

5 Great has been the Controversy among Anatomists, whether this Water or Lympha is always present in the Pericardium of the living Animal: Some affirm that it ought of Necessity to be there in the healthy Animal, and others assert that it never comes there but by Disease or Death. This Argument we shall decide without refuting either Opinion, as follows: It is certain from Anatomy, that a good deal of this Water is contained in the Pericardium of every Person who dies a lingering Death; and it is equally certain, that in those who are kill'd or die suddenly there is little or none to be found. To account for this, it must be observed that the Interstices in the Abdomen, Thorax, and all other Cavities of the living Animal, are repleniſhed with moist Vapours, discharged by exhaling Arteries, the Existence of which in the Superficies of the Heart and its Auricles is proved by Injections: But this Vapour will be discharged more plentifully into the Cavity of the Pericardium, as the Membrane of the Heart is very thin, and as the Blood of its coronary Arteries is propell'd very swiftly and copiously in each Systole; with this Moisture the Heart will be lubricated, and that Friction prevented, which might inflame and occasion its Adhesion to the Pericardium. But these Vapours must be again received by the absorbing Veins, which probably convey them to the

Lympha-

Lymphatics obſerved by *Nucke* in the Heart, or elſe they would be increaſed to a Dropſy, or become putrid and acrid by ſtanding; they are therefore returned to the Blood again in the healthy Animal. But if theſe exhaling Arteries diſcharge more plentifully than the Veins abſorb, as they muſt do when the Heart labours or palpitates by Diſeaſe or Death, theſe Vapours will be then turned to Water, and this Water will be accumulated to the Quantity in which we often find it. By this means alſo, when the abſorbing Power of the Veins declines, in chronical Diſorders, will be ſometimes produced a Dropſy of the Pericardium; in which Caſe it has been found diſtended with ſeveral Pounds of Liquor. But when a Perſon is kill'd, or dies ſuddenly, the Heart does not palpitate long enough to expreſs this Moiſture in any Quantity; and then the Veins continue abſorbing to the laſt, as they die in full Strength. To conclude, we may be ſenſible how neceſſary this Moiſture is to lubricate and ſeparate the Viſcera, and eſpecially the Heart; from the Hiſtories given us by *Peyerus*, in which the Patients were troubled with the moſt violent Oppreſſions and Palpitations, becauſe for want of this Moiſture the Heart was found dry, and adhering to the Pericardium.

6 The great Blood-veſſels of the Heart are extended near two Inches from its Baſis before they unite with the Pericardium, and thus join that to the Heart. Nor is the Heart pendulous in us as in Brutes; for in the human Body its broadeſt Side lies flat upon the Diaphragm, which is ſuſtained by the Pericardium and Mediaſtinum, and immediately ſubſides if you ſeparate them.

7 This is one of the principal Circumſtances in which human Bodies differ from thoſe of Brutes; for in theſe laſt the Heart is placed according to the

the Length of the Thorax, with its Basis next the Throat, and its Apex towards the Diaphragm, to which its Pericardium is slightly attached: But in human Bodies the Heart is placed nearly in a transverse or horizontal Posture, with its Basis in the right Side of the Thorax, and its Apex in the left, while its broadest and flat Side, from the Basis to the Apex, lies inclined and supported on the Diaphragm. This is the true Position of the Heart in the human Body, notwithstanding the Figures in most of our modern Anatomists are erroneous in this respect, being taken either from one another, or from Brutes; but the Figures of *Vesalius*, *Eustachius*, and *Ruysch*, shew the Heart in its natural Posture. From what has been here said we may resolve the Question, why over-eating causes a Palpitation of the Heart: For since the Heart is only separated from the Stomach by the Diaphragm, when the Stomach is over distended, it will force up the Diaphragm, and press upon the Heart, Hence also you may see how the Heart comes to be pressed up so high in the Thorax of those who die of a Dropsy in the Abdomen, and why it is forced so far down in the Abdomen of those who die of a Dropsy in the Thorax; because the Diaphragm, to which the Heart is connected by its Pericardium, is forced either way by the contained Water.

[8] This Partition is formed above the Union of the two Sacculi, which constitute the Pleura in each Side of the Thorax: But as those Sacculi of the Pleura descend, they recede from each other, and intercept the Pericardium.

[9] The abdominal Viscera require a constant Pressure and Agitation from the Muscles; they have therefore no other Defence; the Brain being without any Motion, is therefore lodged in a Case of mere

mere Bone: But the Heart and Lungs require to have their free and ample Motion, and to be defended at the ſame time; they are therefore ſeated in a Caſe of Bones that continually move, but keep off the Preſſure of the ambient Muſcles. The ſoft Lungs indeed preſs upon the Heart, when they are quite diſtended with Air, but without any Injury to it.

10 If any one ſhou'd aſk why the Heart is not placed in the Center of Gravity in the human Body, that ſo it might more equally diſtribute the Blood to all Parts; it may be anſwer'd, (1.) That it is required to be near the Brain, that it might the more readily ſupply Blood to that Organ by the Carotids for all its Offices; agreeable to which, we obſerve in Man, the Elephant, and the other more ſagacious Animals, that the Neck is but ſhort. (2.) It is placed nearer the Arms than the Legs, as the firſt require greater Supplies to perform their various Actions in Life, which are much more noble, numerous and frequent than thoſe of the lower Limbs. (3.) It could not be placed in the Abdomen, becauſe of the Preſſure there; nor could it be ſeated any where diſtant from the Lungs, as their Commerce in moving the Blood is immediate and inſeparable; for which reaſon it lies in the Head of Fiſh, becauſe their Lungs are there.

§. 183. The two coronary Arteries of the Heart ariſe on oppoſite Sides from the Aorta, a little *above* 1 its ſemilunar Valves; and proceeding in *oppoſite* 2 Courſes, they unite and form one Canal, which ſurrounding the whole Baſis of the Heart, ſends off numerous Arteries, which variouſly communicate with each other by Anaſtomoſes, and are ſpent

in

in an infinite Number of *very minute* [3] Arteries, the ſmalleſt Series of which prevade the whole Superfices of the Heart both external and internal, and pour out a Liquor in the Form of Dew; ſo that the whole Subſtance of the Heart ſeems in outward Appearance to be made up of Arteries and Veins, ramified in the ſame Manner, with a Quantity of *Fat* [4] lodged betwixt them externally. 'Tis remarkable, that theſe Arteries of the Heart are in their *Diaſtole* [5] at the Time when thoſe of all the other Parts of the Body are in their Syſtole. The ſmall Veins of the Heart convey their Blood partly into the *coronary Branches* [6], which paſſing towards the right Auricle, have their *chief Opening* [7] betwixt that and the right Ventricle, into which laſt they alſo open by ſeveral *venal Orifices* [8], as well as into the Auricle: Of theſe Veins it is obſervable, that they are *emptied* [9] while the other Veins of the Body are filled.

[1] About even with the Margin of the Valve which is fartheſt from the Heart.

[2] It was none of the leaſt Diſcoveries of *Ruyſch*, when he obſerved the two coronary Arteries met together into one, from whence all the Branches are ſupplied to the Subſtance of the Heart, and by which means there is alſo an Equilibrium in the Diſtribution of the Blood.

[3] The celebrated *Ruyſch* was perſuaded, in one of his Preparations of the Heart, that the ceraceous Injection had paſſed or tranſuded like Down, thro' theſe ſmall Arteries; from whence he concluded, that the Blood paſſed thro' them in the ſame Manner

Manner in the healthy Animal. But when I examined his Preparation by the Help of a Microscope in the Rays of the Sun, I observed that little Globules of the Injection had been forced thro' the smallest Arteries and escaped into the cellular Substance, which invests the muscular Fibres of the Heart. These smallest sanguiferous Arteries terminate either in Veins, or in lymphatic exhaling Arteries, which discharge the Water into the Pericardium; which Liquor is found of a reddish Colour in Animals that are opened after violent Exercise, as in Hares, Stags, Horses, *&c.* from the violent Action of the Heart and sanguiferous Arteries forcing some of the red Globules thro' the serous or exhaling Arteries; whence people often make Bloody Urine after hard riding or violent Excercise, from the same Cause. Sometimes these small exhaling Arteries are so far dilated as to transmit mere Blood itself, so that after violent Exercise bloody Sweats and Urine have been observed.

4 A Quantity of Fat is constantly found intermixed with the coronary Blood-vessels about the Basis of the Heart; which sometimes abounds so much in Oxen and Swine, which have been fed in the Stall or fatten'd in the Stye, that the Blood-vessels of the Heart are compressed by the redundant Fat; whence too, those People who have the Blood-vessels of their Heart in this Manner overloaded with Fat, are of a sluggish Habit, and of dull Intellectuals: So that from hence we may understand the Scripture Phrase (*Acts* xxviii. 27.) *He hath fatten'd their Hearts, lest they should understand.*

5 The Principal of these opens towards the left Side of the right venous Sinus, and is furnished with a Valve at its Orifice, observed by *Eustachius.*

But

[6] But some open into the Vena Cava itself, just before it enters the Heart; but so that all the Blood from the Substance of the Heart arrives into its right Ventricle, and must pass thro' the Lungs before it can enter the left Ventricle.

[7] Some of them larger than the rest, and described by *Ruysch*; others of them very small, and opening into the little Sinus's in the right Ventricle, into which they transmit Water, Spirit of Wine, and even Wax itself, after Injection. These have been formerly observed by *Thebesius*; and *Vieussens* has made them the Seat of his imaginary Ferment of the Heart. All these small Veins seem to arise immediately from the Extremities of the Arteries, without having any Bibulous Veins: And there are few or none of them that we can observe to open into the left Sinus or Auricle.

[8] This is a Circumstance that ought to be particularly remembered; that when the Heart propells its Blood into the Aorta, it is then pale, constringed and bloodless; which is a manifest Argument, that at that Instant it does not receive any Blood into its Arteries; and therefore the Aorta will be fill'd when the coronary Arteries are emptied: But the Heart, the Instant after its Systole, becomes relaxed, and the Aorta at the same Time contracts itself, by which the Blood is equally forced every way, as well back to the Valves, as forward to the Branches; by which Means it will enter and fill the relaxed coronary Arteries. Hence it follows, that as the coronary Arteries are not filled by the Heart, but by the Aorta, they will be in their Diastole, when the Aorta and all its other Branches are in their Systole; and in their Systole, when all the other Arteries of the Body are in their Diastole; which

makes

makes the first Cause of the perpetual Motion of the Heart. But the next Instant after the Systole of the Aorta, the Heart again contracts forcibly, and, like other Muscles, expells the Blood in its Arteries; so that by the same Action of the Heart the coronary Arteries will be emptied, while the Aorta is fill'd.

9 But as for the coronary Veins, they will emit their Blood either into the right Auricle or Ventricle into which they open, when either of them are relax'd.

§. 184. Besides the forementioned Vessels (§. 183.) the Heart is also composed of muscular Fibres, which arise from four circular *Tendons* [1], encompassing the four Apertures of its Ventricles; in which Tendons most of the Fibres are also again inserted. From these Tendons arise, (1.) a small Number of slender Fibres, which are placed in almost a strait Course from the Basis to the Apex, on the Outside of the right Ventricle, serving to strengthen and assist the Contraction of the subjacent muscular Flesh of the same Ventricle in its Expulsion of the Blood. (2.) Under the preceding Fibres of the right Ventricle, *arise others* [2] from the left Side of the Heart, which ascending obliquely towards the right Side, take a Spiral Course, and terminate in its Basis. (3.) Under the last Fibres there are again others, which ascend from the right Side of the Heart round its left, and encompassing both Ventricles, they rise up and terminate at the Basis of the left Ventricle; so that

that they interſect the Courſe of the laſt Fibres, or run in a contrary Spiral. The two laſt mention'd Series of Fibres (2 and 3.) are in common to both Ventricles, which they equally inveſt; and by their contracting in oppoſite Directions, they ſtrongly and equally conſtringe the Heart on all Sides at one and the ſame Time, preſſing both the Ventricles againſt their internal Septum, and drawing up the Apex towards the Baſis of the Heart in the ſame Action. Theſe Series of Fibres (2 and 3.) are again aſſiſted in their Operation by (4.) another, which paſs in an oblique Curve round the former, to which they are *connected* [3], ſerving to bind them together, and retain them in their Places. But beſides theſe, the left Ventricle has alſo two other thick Series of *Fibres* [4] peculiar to itſelf; the Outermoſt of which, lying under the former, (2, 3, and 4.) aſcend ſpirally all round the left Ventricle, towards the right; and forming Part of the Septum, they terminate in the Baſis of the left Ventricle, whoſe Cavity they entirely ſurround, and are alſo confined or ſecured by other Fibres of their own, like thoſe at (4.). Finally, (5.) under the preceding Fibres is ſpread the very laſt Series, which deſcending in an oblique ſpiral Courſe from the Baſis of the left Ventricle, towards the right Side of the Heart, compoſe the internal Subſtance of the left Ventricle; and after compleating the middle Septum of the Heart, the Fibres are ſpent in Curves of different Lengths, and appear variouſly con-

torted. *Add to these* [5], that the fleshy *Columns* [6], and the small Evacuations in the Sides of the left Ventricle, do fitly dispose it for a very strong and close Contraction, as well by its own proper Fibres, as by those in common to both Ventricles: While the other Threads and smaller Columns, formed in either of the Ventricles, serve to open the Valves when the Heart is dilating, and to keep them shut while it is contracting.

[1] The Margin of the arterial Aperture in each Ventricle is made up of compact Fibres, formed into a white callous and perfectly tendinous Substance. But the circular Tendons of the venal Orifices, tho' pretty firm, are not so callous as the former; but are more fleshy, and ten times weaker. The right venal Orifice is composed from three Orders of Fibres, (1.) from those of the Heart, (2.) the Fibres of the lower Basis of the right venous Sinus, (3.) from the Fibres of the right Side of the Auricle. But the elliptic Tendon of the left venal Aperture is connected two thirds to the left Sinus, and one third Part to the left Auricle. From the Tendons now mention'd arise all the muscular Fibres in the Heart. The left venal Tendon is stronger than the right, and the left arterial Tendon stronger than any of them. These Tendons sometimes ossify in very old People, and in some Animals.

[2] These with the preceding arise from the Tendon of the pulmonary Artery, and are inserted into that of the Aorta; that is, from the whole Circumference of the Back of the right Ventricle arise Fibres, which descending to the Apex of the Heart, invest both its Ventricles superficially, without

without touching its Septum; and then ascending obliquely, they make the third Series of Fibres.

3 For none of the Series of Fibres hitherto described are free from each other, but closely connected and bound together by Fibres, partly muscular and partly tendinous; which Connection is the more firm, as the muscular Fibres of the Heart are stronger.

4 These arise from the Tendon of the Aorta, and are inserted into it again; they descend obliquely under the former Strata to the Apex of the Heart, where they are contorted into a strong fleshy Turbin; from whence ascending spirally, they at length terminate in the Orifices of the left Ventricle, and compose the last Series. These two Series (4 and 5.) belong only to the left Ventricle, and compose its Septum. If we cou'd take them out from each other, we shou'd have two distinct Bags, having each their proper Cavity. The Mechanism of all these Fibres were first discover'd and represented by *Lower*, whose Treatise on the Heart I have gone thro' ten times, and always with new Pleasure.

5 Suppose a Man to have but one Ventricle in the Heart, *viz.* the left, and let that be composed of two Series of muscular Fibres running in a spiral Course, but contrary to each other, from the Basis of the Aorta to the Apex of the Heart, and from the Apex to the Basis again, in an opposite Course. Suppose also that it has but one Vein and one Artery; this Man would be in the Condition of Frogs and Fish. If now another shorter and broader Ventricle be added, formed by the right Side of the preceding one behind, and by its own Flesh before and towards the right Side; and let it consist of two Series of spiral Fibres running in contrary Directions, and retained by straiter ones

externally; the ſpiral ones being alſo continued round the left Ventricle; you will then have that Ventricle compoſed of four Series of Fibres, and the right Ventricle compoſed only of two Orders, retained by a few ſlender ſtraiter Fibres. Thus you will have a factitious Machine or Heart, having its left Ventricle longer and narrower than the right. Nor ought you to imagine what I have been ſaying to be either falſe or impracticable, ſince it is the very Courſe taken by Nature, as *Malpighi* obſerves in the Chick, in which, at firſt, appears only a crooked Tube inſtead of a Heart, which by degrees grows into a Heart, and two Auricles, at a Diſtance from each other; at length the two Auricles conjoin, as the two Ventricles did on the fifth Day of Incubation.

[6] If the Heart was ſmooth internally, or if many of the muſcular Fibres of the Ventricles did not ſtrike out and terminate in muſcular Papillæ, its Ventricles could never entirely empty themſelves: So that we may reckon theſe the eighth and laſt Series of Fibres, and which are not inſerted into any of the former Tendons.

§. 185. Theſe Fibres (§. 184.) *ariſe* [1] from the Branches of the eighth Pair of Nerves, which enter the Heart in a great Number betwixt the *Aorta* [2] and pulmonary Artery; from whence they are diſperſed into the Auricles and Ventricles, and conſtitute their muſcular Fabric, eſpecially in the capacious Ventricles, which are of equal Dimenſions, and thus adapted to perpetual Contractions by the conſtant and powerful Action of their own Fibres without impairing their Structure.

As

[1] As the muſcular Fibres of the Heart are continued from the nervous, they therefore contract towards their Origin; nor ought any body to think they are continued from the Nerves becauſe they look red, for that proceeds from the Blood in the ſmall Veſſels ſpent on them, which being waſhed out, they look pale.

[2] This Courſe of the Nerves is admirably well deſcribed by *Lower*; and it is principally this Courſe of them, betwixt the Aorta and pulmonary Artery, (with what we ſaid of the coronary Arteries at §. 183. *ult.*) by which we ſhall explain how the Heart by its Contraction becomes the Cauſe of its own Relaxation, and how by its Relaxation the Cauſe of its Contraction is again renew'd. For it muſt be obſerved, that a Muſcle becomes paralytic when it is deprived of its arterial Blood and nervous Juice, as we ſhall ſhew the Heart is by its Contraction. 'Tis certain that when the Heart contracts, it dilates the pulmonary Artery and Aorta, which will compreſs the Nerves paſſing into the Heart betwixt them; and the ſame Contraction of the Heart will alſo force the Blood out of its coronary Arteries: Thus therefore the Heart's own Contraction will cauſe it to become relax'd or paralytic. But the Heart is no ſooner relax'd than its Subſtance becomes ſoft, and the two great Arteries contract themſelves into a leſs Diameter, forming a ſufficient intermediate Space to free the intervening cardiac Nerves from Preſſure; whence will be preſent the firſt Cauſe neceſſary to the Motion of a Muſcle (§. 402. N°. 8.); and at the ſame time the Aorta by its Contraction will force its Blood that lies next the Heart, into the relaxed coronary Arteries; whence the ſecond Cauſe neceſſary to move the Heart (§. 401.); at the very ſame Time too the Ventricles will be fill'd

with venal Blood by the Contraction of the Auricles, and hence the third or acceſſory Cauſe of the Heart's Motion, (§. 159. N°. 8.) Laſtly, it appears that the Nerves of the Heart ariſe from the Cerebellum; for if the Cerebrum be injur'd, the Heart does not contract at all weaker than before; but if the Cerebellum be wounded, it ſuddenly ſtops. But as the Cerebellum has no Communication with the Body but by the Medulla oblongata, or by the Spinalis, the Heart has therefore Nerves from both of them; ſince from the Medulla oblongata ariſe the Intercoſtal and eighth Pair; and from the ſpinal Medulla ariſe various Branches, which unite with the Intercoſtal.

§. 186. It is therefore apparent from what we have advanced (§. 184, 185.) that the left Ventricle acts by an orbicular Contraction of its own Fibres, and the right Ventricle by a ſemi-orbicular Contraction, the left Ventricle being alſo aſſiſted by the common exterior Fibres that ſurround both. This will appear evidently from diſſecting the Heart and viewing its Structure.

The left Ventricle being a diſtinct Cone dilates itſelf every way, and contracts within its own Cavity, ſince the Septum belongs entirely to this; but the right Ventricle is an Addition only to the left, and contracts itſelf towards the Septum, which belongs to the left, as towards its fixed Point.

§. 187. The Heart then and its Auricles are *real Muſcles*[1], and act with a muſcular Force; for

for its ſeveral Series of Fibres (§. 184.) being ſhortned in their Action, will contract the *Length*[2] of the Heart, and increaſe its Breadth, alſo at the ſame Time that they exactly diminiſh or contract the Capacity of both Ventricles, they will dilate the *tendinous Aperture*[3] opening into the two great Arteries, cloſe the Valves in the venal Orifices, and expell their contained Blood with a conſiderable Force by the ſame *Action*[4], thro' the dilated Orifices into the Arteries. This is the Syſtole or *violent*[5] Contraction of the Heart, in whoſe Structure there ſeems to be a latent and ſurprizing Propenſity to contract and dilate alternately; even ſo as often to move in that Manner after the Animal is dead, and itſelf taken out of the Body, and even after it has been cut in Pieces.

[1] Its fixed Point is in the Tendons of the arterial and venal Apertures in the Baſis of the Heart, its moveable Point is the Apex, and the Weight is the Blood, againſt which the Apex and Sides act or preſs, as againſt a ſolid Body, which the Blood at that Time reſembles in its Reſiſtance.

[2] They incurvate and draw the Apex of the Heart towards its Baſis.

[3] Their ſemilunar Valves are firmly inſerted into the Coats of the Arteries themſelves, next the Heart; but their Margins lie looſe and fluctuating from the Sides of the Artery towards its Axis: So that when the Blood comes from the Heart, it will preſs theſe Valves cloſe to the Sides of their Artery, whence they ariſe; and when the ſame Blood returns again towards the Heart by the Con-

traction of the Aorta, it will distend or fill out these Valves and close them together. But while the Fibres of the Heart, extended from the arterial Orifices to its Apex, are contracting and drawing the Apex towards the Basis, the Tendons in the arterial Orifices of the last will be in some Degree opened. But if the arterial Trunks are too elastic or resisting to the Ventricles of the Heart, these last will be considerably dilated by the Blood which they are incapable of expelling: Hence arise Aneurysms of the Heart, many of which are described by *Lancisi* in his Treatise on that Subject.

[4] This Action is performed very swiftly, since in the Space of a Second of Time, or the sixtieth Part of a Minute, the Ventricles are both dilated and again contracted. But we shall not be much surprised at this Velocity of the Blood, and Motion of the Heart, which seem'd incredible to *Riolan*, if we consider the great and inconceiveable Velocity with which the Muscles of Vocification act when we sing or speak. For by these we readily pronounce a Chain of ten Letters in the Space of a Second, and each of those Letters are accented by distinct and successive Actions of the several Muscles employed.

[5] This being properly the Action of the Heart, arises from the Impulse of the nervous Juice into its Fibres, by which they are dilated and shortned; and from this Defect we always find the Heart in its Diastole, in dead Subjects.

§. 188. It is also evident that the Blood is thus *forced out of the Heart* [1], and propelled by its muscular Contraction, from its violent starting out of a Wound made in the pulmo-

nary

nary Artery or Aorta near the Heart; as alſo from the violent Expulſion of the Blood out of a Wound in the Ventricles of the Heart, made by turning the Cone upward, cutting off its Apex tranſverſly; and by the Preſſure againſt one's Finger inſerted into the Wound, together with the Turgeſcence, Hardneſs, Tenſion and Paleneſs of the Fibres; which alſo demonſtrate the Contraction to follow, and not to precede the Repletion of its Ventricles, which are by that Contraction empty'd the Inſtant following.

[1] The Heart in its Syſtole contracts the Cavity of its Ventricles, which Contraction muſt therefore force the Blood out of thoſe Cavities into the Arteries; but in doing this, the Heart removes not only the Weight of the Blood in its Ventricles, but alſo the Reſiſtance of the whole Maſs of Blood in the Body; all which muſt be urged forward to make room for receiving that which comes next from the Heart. This Reſiſtance of the Blood is of the ſame Nature with that in all ſolid Bodies, and therefore the Heart may be conſidered as contracting itſelf about a Solid, whoſe Reſiſtance it overcomes by a ſuperior Force; which expelling the Blood, thereby dilates the arterial Orifices as with a Wedge, while at the ſame Time thoſe Orifices are alſo dilated in Part by the Contraction of the muſcular Fibres of the Heart inſerted into them.

[2] 'Tis computed that the Heart in its Diaſtole receives, in its Ventricles and coronary Blood-veſſels together, about five Ounces of Blood; all which is by its Syſtole forced into the Arteries; and

and muſt therefore make a great Difference betwixt the State of it in the Syſtole and Diaſtole.

§. 189. If the Nerves of the *eighth Pair* [1] be compreſſed by Ligature, or cut aſunder in the Neck, the Motion of the Heart weakens, ſoon after palpitates with great Anguiſh to the Animal, and at length ceaſes, and therefore from theſe Nerves proceed the Origin and Continuation of the Heart's Contraction; which yet requires, like all other Muſcles, Supplies of Blood by its coronary Arteries, and into the Cavities of its Auricles and Ventricles [2].

[1] This is a remarkable Experiment of *Lower*, who obſerves that Dogs, who have the Nerves of the eighth Pair compreſſed by Ligature, do not ſurvive above a Day or two. They do not expire ſooner, becauſe there are ſome ſmaller Nerves ſent to the Heart from the Intercoſtals, which can hardly be any way compreſſed. But if, after opening the Cranium, you compreſs the Origin of thoſe Nerves, *viz.* the Cerebellum or Medulla oblongata, then the Motion of the Heart is immediately ſuppreſſed, becauſe you totally intercept the Paſſage of the nervous Fluid or Spirits to it. This laſt Experiment has been made by *M. Duverney*, who, after tying the Medulla oblongata, obſerved the Heart to ſtop from its Contractions; but upon relaxing the Ligature, it again recover'd its Motion.

[2] But beſides thoſe Cauſes there ſeems to be others not yet known; ſince the Heart has been ſeen to leap out of a Veſſel of Water by its Contraction, after it has been cut from its Nerves and Blood-veſſels, and taken out of the Body. The

Heart

Heart of an Eel beats about an hundred Times after it is taken out, and when it ſtops, it will again be put into Motion barely by the Warmth of the Hand. But even when it has done moving in the Hand, it may be again put into Contraction by pricking with a Needle: Alſo the Heart of a Dog, being quickly taken out of the Body and thrown into a Veſſel of Water, will continue its Syſtole and Diaſtole for a conſiderable Time.

§. 190. The Blood being thus almoſt entirely expelled out of the Ventricles and Veſſels of the Heart by its Contraction (§. 187, 188.) its muſcular Fibres then grow flaccid, from the Compreſſion of their Nerves by the Dilatation of the large Arteries; and the coronary Arteries being at the ſame time empty'd, the Ventricles become longer and narrower, the Diſtance betwixt the Baſis and Apex is thus increaſed, and the Contraction or Preſſure of the Sides internally is quite removed; ſo that the mitral and tricuſpid Valves being drawn towards the Apex of the Heart, in its Elongation, by their annex'd muſcular Columnæ, the Ventricles will then be fill'd by the Contraction of the Auricles and venous Sinus's, which makes the natural or unactive State of the Heart, termed *Diaſtole* [1].

[1] Every Muſcle at reſt is ſoft and flaccid, but when contracted they are in a State of Violence or Action, cauſed by the Influx of Juice by the Nerves and of Blood by the Arteries.

§. 191. But that the Ventricles of the Heart are in its Diaſtole filled with Blood, is demonſtrated to us by opening one of the large Arteries near the Heart; and if the Heart of a living Animal be turned upward, and cut tranverſly, the Ventricles will appear in their Diaſtole to receive and not diſcharge the Blood; which we are alſo aſſured of by Inſpection in Animals open'd a little before Death, and from one's feeling no Preſſure in the Diaſtole againſt their Finger, when inſerted into the Ventricles by an Inciſion. It is therefore evident the Blood does not paſs out of the Heart from any Rarefaction, but from its muſcular Force.

§. 192. The *Chyle* [1] therefore being mix'd by a little at a Time with a large Quantity of venal Blood, is then more intimately mixed, attenuated and ſhook together therewith by the muſcular Action of the Heart, and the Fabric of its muſcular Columnæ in the right Ventricle, from whence they are propelled together into the pulmonary Artery.

[1] From what has been ſaid of the Heart, its Action appears to be, (1.) To receive the venal Blood, ſhake it ſtrongly together and attenuate it; ſince the Blood is ſwiftly divided into many ſmall Portions by the muſcular Columnæ. (2.) To make a more intimate Mixture of the Chyle with the Blood, and to render both of them more fluid, by joining the very highly attenuated Blood of the coronary Veſſels, thro' which it paſſes ſwifter than any other Veſſels. But this Mixture of Blood from

from the coronary Veſſels is made only in the right Auricle and Ventricle, ſince that in the left, which has paſſed ſwiftly thro' the Lungs, does not ſtand in need thereof, to prevent its Maſs from congealing, to which the Blood has naturally a ſtrong Inclination; and from whence it eaſily runs into polypous Concretions for want of ſufficient Motion in the dying Animal. (3.) The laſt Action of the Heart is the Propulſion of the Blood into the Arteries, and maintaining its Fluidity. In this Action the Heart muſt exert a very conſiderable Force, ſince it overcomes the Reſiſtance of all the Arteries in the Body; the ſame Force will alſo appear to be great from the muſcular Fabric of the Heart, if compared with that of the ſmall Inteſtines; which laſt, tho' their Action is ſo very conſiderable, have not their muſcular Coat above the thirtieth Part ſo thick as the Ventricles of the Heart.

[2] The right Ventricle propells about two Ounces of Blood into the Lungs, in every Second of Time; and the left Ventricle diſtributes, at the ſame Time, about the ſame Quantity of Blood by the Aorta thro' all Parts of the Body. Some indeed imagine the Quantity of Blood expell'd in each Syſtole of the Heart, to be much leſs than that here mentioned; but this Computation is moſt agreeable with the Capacity of the Ventricles in the human Heart, and with the Obſervations made on the Quantity of Blood expell'd in each Syſtole of the Heart in Dogs open'd alive. A leſs Quantity would not dilate all the numerous Arteries at each Syſtole of the Heart, in the manner we obſerve; and even a large Ox expires in eight Minutes, by dividing an Artery which lets out thirty Pounds of Blood, all drove out by the Contractions of the Heart: Whereas if the ſame Artery be

open'd

open'd in a dead Ox, when the Heart is ſtill, very little Blood comes out, and with no Force.

The Structure and Action of the Lungs.

§. 193. IN order therefore to know what further happens to the Blood and Chyle now arrived in the Lungs, we muſt next examine the Structure of that Viſcus, as it is a Compages of Air-veſſels and Blood-veſſels.

§. 194. The *Air-veſſels* [1] of the Lungs have the Power of taking in and blowing out this elaſtic Fluid by the Noſtrils and Mouth, thro' the *Rima* [2] or oblong Aperture in the *Glottis*, which is kept naturally and conſtantly open, and is formed by the Conjunction of the two *Artænoide* [3] *Cartilages*, cover'd with the *Epiglottis* [4], which is naturally elevated by a ſtrong *Ligament* [5] in its upper or anterior Surface, which is ſometimes muſcular. This ſame *Rima* of the Glottis is alſo contracted and defended in ſuch a manner, that no other Body than Air can paſs into the Lungs; for when any other Body approaches, the Epiglottis is depreſſed over the *Rima* by its Arytæno-epiglottid and Thyro-epiglottid Muſcles, and at the ſame time the Arytenoide Cartilages are alſo contracted, or approximated by their *Arytænoideus rectus* Muſcle, which is ſingle, and by their two *Arytænoidei obliqui*, which croſs each

each other upon the former; to which add the Thyroarytænoide and *Hyothyroide* [6] Muſcles compreſſing the upper Part of the Larynx in its Elevation. The Rima is again dilated by the Crycoarytænoidei poſtici and laterales, as alſo by the Sternothyroides, which pulling down the Larynx from the Epiglottis, gives a free Paſſage for the Air to enter and return.

[1] That the Larynx has no Share in Reſpiration, but only ſerves to ſhut the Trachea and form the Voice, we are aſſured by Experiment in a Dog, whoſe Larynx being divided from the Trachea, he continues nevertheleſs to breathe freely through the Wound, only without howling or making any Noiſe.

[2] The Rima is ſeated almoſt horizontally, and intercepted by the Conjunction of Cartilages, Glands, and two Ligaments, which are beſt deſcribed by *Morgagni*. This Aperture is long, and not round, that it might be more eaſily cloſed, and alſo prevent any Bodies from ſlipping into the Trachea which wou'd excite the moſt dangerous Symptoms, and even Death, as I obſerved to you in (§. 70. *ult.*) of a Gentleman that was ſtrangled at a Feaſt by a Morſel ſlipping into the Windpipe: But the Rima being long and narrow, is the better fitted to keep out the Duſt, Inſects, and Particles of the Aliment.

[3] Theſe Cartilages are furniſh'd with Glands, which when deprived of their Mucus occaſion a Hoarſeneſs, and when tumified, a Quinſy: Their Mucus ſerving to lubricate the interior Surface of the Larynx. But round the Larynx above, or on its Outſide at the Root of the Tongue, there is a great deal of Mucus ſupplied from the glandular

Expanſion

Expanſion of *Vaterus*, and the *Cryptæ* or ſimple Glands of the Epiglottis. Beſides theſe, the internal and ſmooth Membrane inveſting the Cavity of the Larynx is alſo full of very ſmall Glands, which diſcharge a lubricating Juice; which being obſtructed, occaſions a Hoarſeneſs and Difficulty of Breathing.

4 There are properly but four Cartilages of the Larynx, ſince the Epiglottis does not make up any Side of the vociferous Tube, but ſerves as a Cover to prevent any Mucus, Drink or Particles of the Aliment from falling therein. It was neceſſary for the Epiglottis to be an elaſtic Cartilage, that its own Weight might not depreſs it, and yet that it might yield to the Preſſure of Liquors, *&c.* to cloſe the Larynx, and prevent their eſcaping into the Windpipe to the Hazard of Life. For no Perſon can ſurvive without quick Supplies of freſh Air this way; and if any Particle of the Aliment falls in, or even a Drop of Liquor, it is immediately expell'd by a ſtrong convulſive Cough, or elſe a Suffocation will follow; which may yet be prevented by inſtantly performing the Operation *Tracheottomy*, that is, dividing the Trachea juſt under the Larynx: For that Wounds of this Part are curable, and not mortal, may be concluded from the one Inſtance (among many others) of a Man who recover'd after his Throat had been cut by Robbers, in *Philoſ. Tranſ.* N°. 258. And tho' theſe Cartilages are very thin and flexible, yet they are connected to each other by very ſtrong Ligaments.

5 This Ligament is compoſed by a Reduplication of the external Integument of the Tongue; and its Place is ſupplied in Oxen, Sheep, and other Animals, by diſtinct Muſcles ſerving to elevate the Epiglottis.

The

[6] The Muſcles which approximate the Sides of the Glottis when we ſpeak or ſing in an acute Strain, and which cloſe the Glottis when we hold in our Breath, muſt exert a very conſiderable Force; ſince they reſiſt and overcome the Force of the Air confined in the Lungs, and endeavouring to expand itſelf, or eſcape; for we can ſo ſtrongly contract the Cartilages of the Larynx by their Muſcles, that tho' the Noſe and Mouth be open, yet the Air can neither paſs into nor out of the Lungs; by which means the Slaves of *Angola* frequently ſuffocate or ſtrangle themſelves voluntarily, when they think themſelves hardly uſed by their Maſters; and in this Caſe, no Remedy will ſo well ſucceed as Stripes and Blows to make them cry out or breathe; and if this fails, they preſently expire. But thoſe Muſcles which dilate the Glottis are not near ſo ſtrong as the former, which contract it; ſince we do not uſe them to open, but only to enlarge the Rima of the Glottis, when we expreſs grave Tones; for that this Part naturally remains open of itſelf, is apparent in our Sleep, at which Time we breathe freely tho' the Muſcles are relaxed.

Theſe Muſcles draw the whole Larynx towards the Root of the Tongue, and cloſe the Rima of the Glottis.

§. 195. In the next Place, the Aſpera Arteria or Windpipe, conſiſting of *ſemicircular* [1] cartilaginous Segments, with their back Parts membranous, and connected together by ſtrong *muſcular Ligaments* [2], gives a free Ingreſs and Egreſs to the Air from the Glottis through its Capacity, which is always open, and lined with a ſmooth lubricated *Membrane* [3]; ſo that it will expand circularly by the Air, give way

to the Gula in Deglutition, follow the Posture or Bending of the Neck, and become either elongated or contracted as there may be Occasion. But the whole Membrane, which makes up the Back of the Trachea, where the circular Cartilages are deficient, is beset with small Glands, which separate an *unctuous* [4] Humour, discharged by their Ducts, perforating the tendinous Coat, into the Cavity of the Trachea, whose Surface is hereby lubricated and defended.

[1] These Cartilages are much more than semicircular in Brutes, forming more compleat Circles in them than in the human Species; because the first have their Necks pendulous, with the Windpipe under the Gula. But it was necessary for the annular Cartilages of the Trachea to be more imperfect or membranous in the human Species, (1.) that the Oesophagus might not be compressed or resisted in Deglutition by the harder Cartilages; and, (2.) that the Trachea might the more readily contract, elongage, and conform to the various Motions of our Necks, and dilate itself laterally when we utter grave Tones.

[2] The intermediate Spaces betwixt the Cartilages of the Trachea, which make about a fourth or fifth Part of it, are filled or compleated with two Series of muscular Fibres. The posterior or internal muscular Fibres draw the Cartilages into Contact with each other, to utter acute Tones; and when they are relax'd, the Cartilages separate and recover their former Places by their own Elasticity. But the exterior or longitudinal Series of muscular Fibres arise each from the upper Margin of the lower Cartilage, and are inserted into the inferior

Edge

Edge of the upper Cartilage; and by drawing the Cartilages together, they ſhorten the Trachea, and make it yield a grave Tone. Theſe Muſcles are therefore under the Influence of the Will, and I uſually entitle them *Meſochondriaci*, from their Situation betwixt the Cartilages.

3 So extremely ſenſible, that Nature has placed it as a Guard to watch at the Door of our Breath and Life, that we might not be ſuffocated by any Particles falling into the Trachea: For all Bodies irritate it but the pure Air; even a Drop of clear Water excites a convulſive and troubleſome Cough, which does not ceaſe till the Liquor is ejected by the Impetus of the Air, drove out by the Contractions of the Diaphragm; which Precaution was neceſſary to prevent our Lungs from being injured unknown to us.

4 This Liniment, which lubricates the Membranes, and prevents their drying and ſhriveling with the Air, is ſecern'd into *Cryptæ* by ſimple Glands, ſeated in the membranous or back Part of the Trachea, where the Cartilages are wanting, while the continual Motion of the Trachea promotes the Secretion. It is ſometimes ſpit up in a Morning under the Name of Phlegm, after it has been accumulated and inſpiſſated by the Air in the Night: And when it is deficient, the Air itſelf proves ſo irritating to the Membranes, as to excite a troubleſome Cough, often attended with a ſpitting of Blood; but when totally wanting, or dry'd up, the Voice becomes ſqueaking, as if it came thro' a metal Pipe, which is judged a mortal Sign by *Hippocrates*. It is retained in the *Cryptæ*, or ſmall Veſſels, to thicken, and be ready for Expreſſion when it ſhall be moſt wanted.

§. 196. The Trachea dividing itself into *two* [1] about the fourth Vertebra of the Thorax, is still composed of Cartilages that are imperfect Rings [2], compleated on their back Part with the aforesaid glandular Membrane; but it immediately afterwards divides into an infinite Number of Branches on each Side, having each the same Structure as at §. 195. only the cartilaginous Segments are more and more compleatly annular; and the *Lacunæ* discharging the oily or mucous Liniment, continue to open internally betwixt their tendinous or connecting Fibres: These Branches, or Bronchia, go off in acute Angles, and lie incumbent on each other; becoming gradually smaller and thinner, till at their Extremities the cartilaginous Texture is changed into a thin Membrane formed into many pliable Cells or Sacculi, all opening into the Extremity of the Branch from whence they arise; and these *Cells* [3], being formed into *Vesiculæ* and Bundles, compose Lobes, of which there are five in the Lungs, two in the left, and three in the right Side of the Thorax; which again make up the whole Body of the Lungs, so far as it is an Air-vessel.

[1] Of which, that on the right Side divides into three Branches, behind the Curvature of the Aorta, and composes so many Lobes of the Lungs; while that on the left Side only divides into Branches, and composes two Lobes.

The

[2] The cartilaginous Segments of the Trachea do not become compleat Rings immediately upon its Diviſion into the Bronchia, as many have imagin'd; but their membranous Deficiency ſtill continues, tho' leſs, as the Bronchia ramify farther, as hath been long ago juſtly obſerved by *Euſtachius*. This is therefore an Argument that the Deficiency in the Cartilages was not made barely for the Sake of the Oeſophagus.

[3] This Structure of the Lungs was firſt beautifully demonſtrated by *Malpighi* in a Frog; in which the Lungs appear compoſed of two Bladders, divided into many hexagonal Lobules, connected to each other, and their Surfaces ſpread with Blood-veſſels. The ſame Structure obtains in the human Lungs, but more obſcurely, becauſe of the exceeding Smallneſs of the Cells. But thoſe Cells are found compoſed of two Membranes, one a Continuation of the external Integument of the Bronchia, and the other of the internal Membrane of the ſame Bronchia; but betwixt the Membranes of the Cells we have no Appearance of any Cartilage as we have in the ſmall Bronchia. From hence it follows, that as the Trachea and Bronchia are cartilaginous all the way from the Larynx to the Cells, and as the Reſiſtance of the Cartilages gradually leſſens towards the Cells, the Air by its Weight will have a free and ſpeedy Courſe into the Cells, where it meets the leaſt Reſiſtance. The Lungs will therefore be diſtended moſt where they reſiſt the leaſt, and where the Columns of Air are longeſt.

§. 197. If then the Air be *admitted* [1] thro' the Glottis into the Trachea and Bronchia, as it is an elaſtic and heavy Fluid, it will inflate

or diſtend thoſe Tubes with their Branches and Cells; all which will be hereby enlarged both in Length and Diameter; at the ſame Time the Branches of the Trachea will *ariſe* [2], and ſeparate into larger Angles, their Lobes will be elevated or fill'd, and the Cells will be diſtended from their flat or compreſſed Figure into one more ſpherical or capacious; and from hence, the Spaces betwixt the cartilaginous Segments, Branches or Bronchia, and Veſicles of the Lungs, will be increaſed, and come *leſs into Contact* [3], *in Proportion* [4] as the Lungs fill with Air; the Quantity of which may be known by blowing into a Veſſel furniſhed with a Barometer, or by the ſwelling of the Thorax in a Bath.

[1] The Air is not admitted into the Lungs but by the Dilatation of the Thorax; for when that is contracted, the Air in its Cavity and in the Lungs is of the ſame Tenure with the Atmoſphere; ſo that an Equilibrium ariſes from the internal Air reſiſting the external, whoſe Preſſure is equal to a Column of Mercury 28 Inches high, or 32 Feet of Water. But ſo ſoon as the Thorax is dilated, the Lungs follow the Enlargement of its Capacity; and their included Air being thus rarified or exended into a larger Space, does no longer reſiſt the external Air; which therefore enters into the Lungs in ſuch a Quantity, as will reduce the rarified or included Air to the ſame Denſity with the external. The firſt Effect therefore of the Air ruſhing into the Lungs will be (1.) the Extenſion of it longitudinally; after which follows (2.) an Expanſion of it laterally; from both which ariſes

(3.) a

(3.) a Change in the angular Position of the Vessels, and the Increase of their intermediate Spaces; and lastly, (4.) a Dilatation of the Vesicles or Cells.

2 The Bronchia do not all descend; for since the Trachea, from whence they arise, descends into the middle of the Lungs before it sends off the Bronchia, the uppermost of them may be properly said to ascend; and all of them distended with Air, are thereby elongated, enlarged laterally, and placed in larger or more obtuse Angles, assuming a Form that renders them the most capacious. It is also easily demonstrable, that a Trunk dividing into two Branches, will be the most capacious when the Branches meet the Trunk at right Angles; for since Cylinders of the same Base are to each other as their Heights, an oblique Cylinder will not be more capacious than a streight one of the same Base that is shorter; and therefore an oblique Cylinder reduc'd to a streight one, without changing its Length, will be more capacious, because its Height increases, and it will be still more capacious if elongated. When the Thorax is contracted, the cartilaginous Rings of the Bronchia are drawn together by their Muscles, and by the same means the Sides of the Trachea are absterged, and the Mucus carried off by the Impetus of the Air in coughing.

3 The empty Cells lye with their flat Sides close to each other, but when distended spheroidically as Spheres touch in the fewest Points, the Blood-Vessels therefore will be most at Liberty, and Circulation through the Lungs freest in Inspiration. That all hollow Membranes do by an equable Distension of their Sides become spherical, is proved at large by *Bernouli*, *De Mot. Musculor*, §. x and that the Pressure or Distension of the Sides of

the pulmonary Cells is very great, may appear from the Force of the Air which acts on them.

[4] The Lungs is the largeſt of all the Viſcera; nor ought its Size to be judged of from the Bulk in which it appears in dead Subjects, ſince it is in them very much collapſed and ſhrunk, whereas when they are diſtended with the Air in the living Subject they fill the whole Thorax; ſo that deducting the Heart and pulmonary Blood-veſſels, the reſt of the Space in the Thorax will be almoſt wholly occupied by Air.

§. 198. Here alſo the pulmonary Artery being incurvated immediately at its Riſe from the Heart, divides itſelf into an infinite Number of Branches, diſtributed along with the Ramifications of the Trachea, and poſſibly ſubdividing into all the leſſer Series of Arteries, as ſanguiferous, ſeriferous, lymphatic, *&c.* the ſmalleſt Ramifications of which are ſpread like a *Network* [1] upon the Surfaces of the pulmonary Veſicles, and alſo in like manner upon their Cells or intermediate Partitions, and after forming an Infinity of arterial Anaſtomoſes with each other, they at laſt terminate in correſponding Veins.

[1] We obſerved that the ultimate Ramifications of the Bronchia end in the Veſicles of *Malphigi*; to which add, that the Arteries in their ſmalleſt Diviſions compoſe a reticular Expanſion, running round the ſmall Bronchia without opening into their Cavity, but proceeding forwards ſuperficially till they open into correſponding Veins, without any glandular Fabric intervening. But the laſt Diſtribution

bution of this vascular Plexus is betwixt the two Membranes investing the Trachea, and which compose the Vesicles on whose Superficies the reticular Plexus is expanded, and also round the Trunks of the Air-vessels or Bronchia. Another Disposition of the Vessels is betwixt the Bronchia, in their Intervals, and the last Expansion of them is within the Interstices of the Vesicles, betwixt which is interposed the common cellular Membrane, affording possibly some Oil, but very little and subtle; for the Lungs have the least Fat of any Viscus.

§. 199. The small pulmonary Veins having also their Distribution and Intertexture like those of the Arteries, (§. 198.) receive the Blood brought to them by these last, (after having suffer'd the Action of the Lungs, and lost little or nothing by *Secretions*[1] in the way) and convey it into the larger Branches of the pulmonary Vein, which at last terminate in four Branches still larger, through which the Blood passes into the Sinus of the pulmonary Vein, and from thence into the left Auricle and Ventricle of the Heart.

[1] There are no Secretions made from the Blood of the pulmonary Artery; there is indeed a Secretion made by some conglobate Glands in the Lungs, and by the Cryptæ of the Trachea and its Branches; but then both these are supplied by the bronchial Artery of *Ruysch*. Therefore all the Blood brought by the pulmonary Artery is again returned by the Vein of the same Name, in which the Blood instead of losing gains something from the bronchial Humours taken in by bibulous Orifices, pervious

vious to the Air, and even the Injection of *Ruſch*, and ſeated in the pulmonary Cells. There is alſo ſome Lymph returned into it by the Lymphatics which are very numerous in the Lungs.

§ 200. From conſidering the fore-mentioned Structure of the Lungs (§. 194 to 200.) with the Action of the Air upon them (§. 197.) and the ſwift Courſe of the Blood and Chyle thro' them, we may underſtand what Effects or Changes are produced in thoſe two Liquors by the Force of Reſpiration: Such as,

1. This mixt Humour being drove, by the Force of the adjacent right Ventricle of the Heart, into a crooked, conical, flexible, elaſtic and reſiſting Artery, its component Particles will be *compreſſed* [1], compacted or condenſed, their Points of Contact and Figure will be continually changed, their Cohesions ſeparated, their Sides ground againſt each other, and their Fluidity preſerved; whence the Blood will be fitted to paſs through into the pulmonary Veins in the ſame Quantity as it was drove by the Heart into the Lungs, which is therefore a Strainer to the whole Body; all which holds true, even of the Blood paſſing thro' the Lungs of a Fœtus in Utero.

2. The Motion of the Veſicles in the Lungs, diſtended by Inſpiration, in which they ſucceſſively touch or compreſs each other in *fewer Points* [2]; while the Cells at the ſame Time gradually change their Shape and enlarge their Dimenſions; and the Motion of the Veſicles and Cells gradually contracting themſelves

ſelves in *Expiration* [3]; and the *Elaſticity* [4] of the retained Air continually increaſing by the Warmth after Inſpiration and Expiration, do all of them occaſion the Preſſure made on the Veſſels and Humours of the Lungs to be unequable and ſucceſſive, changing every *Moment* [5]: Hereby then the Blood, Chyle, and their Humours will be reciprocally preſſed, *agitated* [6], *propell'd* [7], ground together, *diſſolv'd* [8] and made fluid, ſo as to be fit to paſs *all of them thro'* [9] the ſmall Veſſels of the Lungs. The Lungs diſtended with Air by Inſpiration look pale, the Arteries and Veins ſpread themſelves, and give leſs Reſiſtance to the Blood impell'd from the right Ventricle of the Heart, while by the ſame means the Courſe of the Blood into the Veins is expedited, and in them accelerated towards the left Ventricle; but when the Lungs are contracted or collapſed, as in violent Expiration, it is hardly poſſible to fill the pulmonary Artery by injecting any Liquor; whereas when the Air-veſſels of the Lungs are inflated, the Blood-veſſels do then eaſily admit of being fill'd.

3. The Chyle therefore which has been prepared in the Mouth, digeſted in the Stomach, elaborated in the Inteſtines, ſecerned in the Lacteals, attenuated at the meſentric Glands, and farther diluted and mix'd in the thoracic Duct, then blended with the venal Blood, afterwards more intimately mixed, diſſolved, and *digeſted* [10] or attenuated by the right Auricle and Ventricle of the Heart, is laſtly impelled

pelled into the conical Branches of the pulmonary Artery, by whoſe Sides being reſiſted, and ſtill urged on behind, it receives a violent Preſſure, whereby its Particles take a *Configuration* [11] ſuitable to compoſe all the ſolid and fluid Parts of the Body.

4. The Chyle and Blood are again very intimately *mixed* [12] in the pulmonary Veins; where

5. They are alſo diluted by the Lympha, which firſt receives the Impreſſion of the Lungs on its proper lymphatic Veſſels, as the Blood did in its Veſſels.

6. By theſe means they ſeem to put on a Form fit for *Nutrition* [13].

7. The *Fluidity* [14] and *Warmth* [15] of the whole Maſs is this way maintained.

8. We have here a very intimate Commixture of *all the new and old Juices* [16], and their ſeveral Particles throughout the whole Body.

9. Laſtly, From hence ſeems chiefly to ariſe that *red and florid Colour* [17] which is ſo eſſential to good Blood.

[1] The nutritious and healthy Parts of all our Juices, which are either of a micilaginous or globular Texture, and kept continually within the Courſe of the Circulation, are all of them compreſſible, and diſpoſed to run into cloſe Coheſion as well as into Contact with the Parts of each other. But we have already ſeen that the Arteries are elaſtic Canals, reſiſting the Force of Dilatation (§. 132.); and that when the dilating Force ceaſes

to

to act, they contract to their firſt Diameter: By this Reſiſtance therefore, in the pulmonary Artery, the Blood will be repell'd towards the right Ventricle, from the conical Sides of the Artery, and again returned in the Syſtole of the Artery towards the ſame Sides, by which means the Particles of that compound Fluid will impinge againſt many Parts of the ſame Veſſel. But this Repulſion of the Blood from the Sides of the Artery is always proportionable to the dilating Force or Impulſe given to that Liquor by the Heart; ſo that by the Inequality of theſe Forces, and Contrariety of their Directions, the Particles will receive a vortical or whirling Motion about their own Axes, and about the Superficies of each other. By the ſame contrary Forces, the Heart impelling and the Artery repelling at the ſame time, the Particles will be alſo compreſſed; and the more, as no Arteries have their Origin and Termination ſo near together as thoſe of the Lungs; to which add the Reſiſtance at their Anaſtomoſes from the Preſſure of the Air in Inſpiration. In conſequence of theſe Cauſes, the fluid Parts will aſſume a ſpherical Figure; for every pliant Body will become a Sphere from an equilateral Diſtention internally, or a like Compreſſure externally. But as the preſſing Cauſe is here external, and as Spheres contain the moſt Matter of any Surface, the Particles will alſo become more denſe and heavy by the ſame means: It therefore follows from hence, that the Parts of the Blood and Chyle aſſume their Sphericity, and augment their Denſity from this Power in all the Arteries, but in none ſo much as thoſe of the Lungs; becauſe the ſame Quantity of Blood paſſes through them, in the ſame time, as the like Quantity is diſtributed all over the Body; and therefore the Blood will paſs with a greater Velo-

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city, in Proportion, thro' this Viſcus, as it is leſs than the whole Body. Thus you have my Theory of Sanguification, or the Chyle made Blood, chiefly by the Lungs; in which Viſcus the Globules alſo acquire that Denſity by which they exceed the ſpecific Gravity of Ale, Water, and other Liquors, one twelfth Part; and which I take to be greater while they are compreſſed in the Veſſels than when only preſſed by the Air. This Compreſſure of the Blood in the Lungs, by which its Parts acquire their Denſity, is greateſt in the Arteries when the Lungs are contracted in Expiration, when it cannot paſs freely into the Veins, and is ſtill urged into the Artery by the right Ventricles.

2 If a Bunch of Bladders were empty of Air, and preſſed cloſe together, they would come wholly into Contact; and this being the Caſe in the Lungs of the Fœtus, they ſink, even in Salt-water; but if, by one common Duct, thoſe Bladders are inflated, by aſſuming a ſpheroidical Shape, and departing from each other, they will touch in but few Points, and leave intermediate Spaces of angular Shapes; and it is in theſe Spaces, however ſmall in the Fœtus, that the pulmonary Blood-veſſels are diſtributed. Hence one may perceive, that when the Veſicles are inflated, and their Preſſure taken off from the pulmonary Arteries, theſe laſt will be then more filled or diſtended by the impelling Force of the right Ventricle; and the Veins being alſo more at Liberty, the Blood will enter them more copiouſly, and return more ſwiftly to the left Auricle; and thus it is that the Lungs, which, before Birth, tranſmitted only one third Part of the Blood from the right Ventricle, does, after Inflation, tranſmit the whole thro' its Veſſels. That the Force with which the Lungs are inflated by

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the Atmoſphere is very great, we know by its Preſſure and Velocity with which it ruſhes into a Vacuum. Nor can we retain the Air long after Inſpiration; for by dilating the Veſicles too much by its Expanſion, the Blood-veſſels will be compreſſed near as much as when the Veſicles are flaccid in Expiration.

3 In this State the Diaphragm returns upwards, the Ribs and their elaſtic Cartilages deſcend, and both contract the Capacity of the Thorax, whereby the Veſicles in the Subſtance of the Lungs are compreſſed, their Sides brought into Contact, and their included Air by that means expell'd. This will diminiſh the angular Spaces betwixt the Veſicles, compreſs the Blood-veſſels there diſtributed, and prevent the Blood from paſſing freely thro' the ſmall Branches of the pulmonary Artery; in which it will be therefore accumulated in Expiration, while the ſame Compreſſure that obſtructed the Blood in the Artery will accelerate it in the Vein by propelling it from the ſmaller towards the larger Branches, and into the left Sinus. The Blood of the Vein then will be accelerated both in Expiration and Inſpiration, and moſt retarded during the Interpauſe or Reſt of the Lungs.

4 The Air preſſes on the Veſicles of the Lungs not only by its Weight, but alſo by its Elaſticity or Spring, augmented by the Heat or Warmth of the Blood in this Viſcus, by which it will be rarified and expanded ſucceſſively, till it becomes as warm as the Blood itſelf. The Air will be therefore warmed by the Blood, and the Blood cooled by the Air, in the Lungs, in Proportion to the Temperature of either; inſomuch that if the Blood moved as ſlow in the Lungs as in other Parts, it would be quite congealed there by a hard froſty Air.

So

5 So long as the Air expands the Veſicles of the Lungs, the Blood will have a free Courſe from the Artery into the Vein; but in different Degrees: For from the firſt Entrance of the Air in Inſpiration, the Veſicles and Bronchia will be dilated gradually, and then a little time will paſs in the Height of the Dilatation; after which, they again gradually collapſe. Hence will ariſe a mutual Attrition betwixt the Blood and its Veſſels, whereby the groſſer Parts will be diſſolved into leſſer, the ſmaller compacted into larger, and the Aſperities abraded from both. All this will be again promoted by the Fabric and Diſpoſition of the Vaſcular Plexus, in which the ſmall Veſſels mutually concur, and then ſeparate like the Marſhes of a Net.

6 This Agitation ariſes from the Parts of the Blood being divided in the recticular Plexus of *Malpighi*; and altogether the ſame Effect happens to the Blood in the Muſcles when in Motion, upon whoſe Fibres the Blood-veſſels are expanded recticularly as in the Lungs; but as the Lungs alſo act with an additional Preſſure from the Air, as well as by their Motion, the Blood will receive a greater Shock and Agitation in them than in the Muſcles.

7 Nothing is ſo effectual for preventing and removing Obſtructions in the Veſſels, as an alternate Preſſure of their Sides, while the Fluid is impell'd thro' them; for thus the leathern Pipes of Fire-engines, when obſtructed by the Mud or Clay of foul Water, are eaſily cleared by the Impulſe of the Water, and moving or varying the Courſe and Direction of the Pipes. And from this Principle it is, that the Veſſels of the Lungs are ſo ſeldom obſtructed, tho' they receive all the crude Chyle, and Cold of the Air.

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[8] Diſſolution is moſt effectually performed by communicating freſh Shocks or Impulſions to the firſt Motion receiv'd by the Parts of Bodies, joined with an Attrition: For it is thus the moſt compact Metals are diſſolved.

[9] The light, ſpongy and multiform Particles of our Chyle wou'd not be capable of pervading the minuteſt Veſſels of the Body, as they muſt do for Nutrition, if they were not firſt highly attenuated, ſmoothed and rounded by the Lungs; in which conſiſts the chief Office of this Viſcus, as ſubſervient to Sanguification and Nutrition. For none of the Chyle is convey'd through the Arteries to any Part of the Body before it has firſt paſſed through, and been divided by the Lungs: But ſhould the Chyle preſent itſelf to the ſmalleſt Arteries without this previous Attenuation of the Lungs, it would from the Structure and Minuteneſs of them be abſolutely unpaſſable, and produce incorrigible Obſtructions; as it never fails to do even in thoſe who have bad Lungs, or breathe leſs frequently, as in the Sedentary, *&c.* It is therefore in the Lungs chiefly, that the Particles of the Chyle receive (1.) a great Attrition, by which they are broke, poliſhed, and rounded; (2.) a Compreſſure, by which they are denſified and formed into Spherules; (3.) a Lubricity and Aptitude for Motion, by being ſtrained thro' the ſmalleſt Veſſels of this Organ. For it is certain, that the Veſſels appear no where more minute than in the Lungs; and thoſe being contracted beyond their natural Diameters in the Expiration of this Viſcus, if the Chyle can paſs freely thro' theſe Obſtacles or Reſiſtances, there is no Danger of its meeting with greater in any of the other Parts before it returns again.

[10] Before our alimentary Juices can be fit to nouriſh the ſeveral Parts of our Bodies, it is firſt re-

quired that they become in all reſpects like the White of an Egg, only more fluid; for we find that barely from this Albumen, attenuated by Incubation, ariſe all the ſolid and fluid Parts of the Chick within the Space of twenty one Days. Now the ſerous or lymphatic Parts of our Blood are thoſe which come neareſt to the Nature of *Albumen Ovorum*; for this Part, ſeparated from the Cruor, has nearly the ſame ſenſible Qualities with the Albumen; the ſame Softneſs, Glutinoſity, and Diſpoſition to harden in *Alcohol Vini*, and in boiling Water, alſo affords the ſame Principles by chemical Analyſis. We alſo know from the Experiments of *Lower*, that the Chyle, which floated viſibly in the Blood a few Hours after a Meal (§. 130.) does, in the Space of twenty-four Hours afterwards, intirely diſappear, and the Serum of the Blood is increaſed in its ſtead. But this great Change is made chiefly by the Action of the Lungs; for the Chyle is beſt diſpoſed to turn into Serum in the time of Sleep (§. 597.); but then all the voluntary Muſcles are at reſt, and the Lungs ſtill continue to labour,

[11] We know that all our Juices appear globular, and that every Particle or Body preſſed equally on every Side, and turned round on its Axis among others, will become ſpherical; but this being the Caſe, in an eminent Degree, with the Particles of the Chyle in the Lungs, it is in them chiefly that their globular Figure will be acquired. What greatly confirms this Action of the Lungs, is the ſwift Motion of the Blood and Chyle, and large Contact betwixt them and the Arteries in this Part. For I am conſtantly confirmed in my Opinion of the ſanguiferous Arteries dividing themſelves into many leſſer Orders, decreaſing in Proportion to the Series of Globules, and that all thoſe Series

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of Veſſels are diſperſed in the Lungs; and therefore I judge that it is in the Lungs, that the Blood and Chyle are prepared and fitted to paſs ſwiftly thro' all the Series of Veſſels in the Body; eſpecially as there are no Glands or ſecretory Organs in the Lungs to retard the Blood. The lymphatic Veſſels obſerved in the Lungs do alſo demonſtrate, that the Branches of the pulmonary Blood-veſſels are not all of them ſanguiferous, but that they divide into ſmaller, conveying Juices more ſubtle than the Blood.

[12] Three Things are required to a perfect Mixture in a compound Fluid, (1.) an Attenuation or Smallneſs of its Parts; (2.) an inteſtine Motion of its Particles in different Courſes and Directions; (3.) a progreſſive Motion or Agitation of the whole Maſs: All which Cauſes are adminiſter'd to the Blood and Chyle in the Lungs; by whoſe Action it is that the Chyle, after it has circulated for ſome Time diſtinguiſhable from the Blood, becomes at length homogeneous with, or undiſcernible from the Blood itſelf.

[13] In order for Nutrition, it is neceſſary for a large Number of Globules to be prepared of different Sizes, that every Series of Veſſels may be ſupplied with thoſe that fit their Diameters. This then will be another Action of the Lungs, to divide many of the larger Spherules into leſſer ones, whence the Fluidity will be increaſed, and polypoſe Concretions prevented. And from the Sphericity and Rotation of the Particles, their Points of Contact will be continually changing, and varying their Directions. Hence all thoſe Particles which eaſily aſſume a ſpherical Figure, may be conſider'd as alimental; thoſe which aſſume it difficultly, as medicinal; and thoſe which do not take that Shape at all, as poiſonous, with reſpect to the Blood and its Veſſels.

14 The Fluidity will be preſerved as well by the Motion of the Globules changing their Contacts, as by their Sphericity, or Smallneſs of Contacts, with the conſtant Agitation and Dilution of them in the Lungs.

15 We obſerved a little before, that the Heat of the Blood was communicated to the Air in the Lungs, and that therefore the Blood was cooled in this Viſcus: But in this Place we again aſſert, that the Blood is heated, as well as cooled, in the Lungs; which, tho' a ſeeming Contradiction to the firſt Aſſertion, is yet true in Nature. The venal Blood in the left Ventricle of the Heart, is ſomewhat cooler than the Blood of the Arteries; and the ſame venal Blood is ſtill farther cooled by the Air in the Lungs: But the very ſame Blood, when arrived in the left Ventricle, is warmer than before it was expoſed to the Air in the Lungs; whence it follows, that the Blood muſt in this Viſcus acquire a Heat more than ſufficient to compenſate the cooling of it by the Air; which Heat muſt ariſe from that increaſed Attrition the Blood ſuffers here; which Attrition is alſo the common Cauſe of the Blood's Heat in all the other Parts of the Body. That the Attrition betwixt the Blood and the pulmonary Veſſels is very great, may be concluded from the additional Preſſure of the Air by which they are forced againſt each other; and the increaſed Velocity with which the Blood flows thro' the Lungs, which are conſtantly working; whereas the Contractions of the Muſcles are only temporary. This Obſervation holds true throughout all Kinds of Animals that have two Ventricles in the Heart, and breathe Air into their Lungs, like ourſelves; even the Blood of the Whale-kind of Fiſh that inhabit the frozen Seas, is equally hot with ours, ſince they breathe.

But

But thoſe Reptiles and amphibious Creatures which do not breathe, or have but one Ventricle in the Heart, have their Blood near as cold as the Element they inhabit: A plain Argument that the Lungs are the chief Inſtruments of Heat in the Blood.

16 We have already ſhown, that the ſeveral Humours mixing with the Chyle (§. 105.) are abſorbed, and paſs with it into the venal Blood; and that the more ſubtle Parts of all the ſecerned Juices which ſtay any Time in their Receptacles, even the aqueous Dew or Vapours of the exhaling Veſſels, are all returned again into the Blood of the Veins, ſince the Arteries return nothing; but all the venal Blood is propelled thro' the vaſcular Plexus of the pulmonary Artery, by the right Ventricle, in the ſame Time that it paſſes by the Aorta to all Parts of the Body, which at leaſt is after the rate of ſixteen Ounces in a Minute; but it is evident, the elaſtic or ſpheroidical Particles of the Blood cannot be thus ſwiftly ſtrained thro' the vaſcular Plexus of elaſtic and reſiſting Veſſels in the Lungs, without making a very intimate Mixture and Attenuation of the ſeveral Humours therein contained.

17 The Blood in the pulmonary Artery is venal and dark-colour'd; but when it has paſſed thro' the ſame into the pulmonary Vein, it is of a beautiful Scarlet: This additional Redneſs muſt have been therefore acquired by the Blood in its Paſſage thro' the Lungs; tho' the Ancients injudiciouſly ſought for the Cauſe thereof in the Liver. Various Methods have been taken to account for this greater Degree of Redneſs in the arterial Blood; Mr. *Boyle* obſerved, that Fleſh being digeſted for ſome Time with Oil of Vitriol turned red, and therefore ſuſpected that ſomething of the like nature happen'd in the Blood; *Lower* and others

derive it from the Nitre in the Air; and various other Opinions have been ſtarted. But they none of 'em conſider'd that each red Particle of the Blood was globular, and compoſed of ſix yellow Spherules, made up each of ſix white Spherules; and that the Blood appeared redder, as there were more of the yellow Spherules compounded together. They alſo did not obſerve, that the Blood of thoſe People was the moſt florid, who were of the ſtrongeſt Habits, and uſed the moſt Exerciſe. They ought to have been acquainted with what *Lewenhoek* diſcover'd, that all our Malt Liquors, Wines, Bread, and all farinaceous Subſtances do conſiſt, both before and after their Formation into Chyle, of ſmall, lax and white Spherules, eaſily diviſible, which mixing with the Blood, are often diſcerned floating in it for a little time after a Meal; but in four and twenty Hours after, no ſuch Spherules are diſcernible in the Veſſels, but they are all converted into large red ones, or ſmaller yellow ones, and ſtill ſmaller pellucid ones. 'Tis true, the whole vaſcular Syſtem of the Body concurs to this Tranſmutation; the Veins mix the crude Chyle and Blood, and the Arteries grind them together with a conſiderable Force: But the Action or Efficacy of the Lungs only, in this reſpect, is equal to that of all the other Parts of the Body; for the ſame Quantity of Blood paſſes thro' the Lungs in the ſame Time that it does thro' the whole Body; and if the Quantity of Blood be compared with the Shortneſs of the pulmonary Veſſels, or Space it runs over, it will give a very great Velocity; to which add the alternate Force or Impreſſion of the Air. Yet are the Lungs not burſt by theſe compreſſing Forces; for the Dilatation of the Lungs, and the Diſtention of their Veſſels, is univerſally determined or limited by the

Thorax

Thorax and Diaphragm on one Side, and by the Atmoſphere on the other. But if you either increaſe the diſtending Force of the Heart, or diminiſh the Preſſure of the Air, the Lungs will then be wounded; for upon the higheſt Mountains, as the *Pike* of *Teneriff*, where the Air is exceeding light, the Blood ruſhes out of the Eyes, Noſe and Lungs, becauſe the incumbent Preſſure of the Air is diminiſhed without any Abatement of the Force of the Heart, which diſtends and burſts the Veſſels. It therefore follows, that the Lungs are the chief Organs of Sanguification; in which Operation they always perform as much or more than all the other Arteries of the Body: For you can no ſooner increaſe the Motion and Attrition of the Blood in any of the other Veſſels, but the Action of the Lungs will alſo increaſe proportionably, Reſpiration will be quicker, and the Blood tranſmitted thro' them more forcibly; nor is it poſſible for the Aorta to receive more Blood than is derived to it thro' the Lungs. *Lower* indeed computes the Power of the Muſcles to be equal with the Action of the Lungs in Sanguification; but neither can the Muſcles tranſmit ſo great a Quantity of Blood as the Lungs, nor with that Velocity, nor have they the other Advantages of this Organ; as, (1.) the Preſſure of the Air, computed by *Keil* at an hundred Pounds, acting immediately on the Blood, from which it is ſeparated only by very thin Membranes. (2.) The exceeding Smallneſs of the Veſſels. The Heart is indeed a very ſtrong Muſcle, and may be judged to conduce more than the reſt to Sanguification, (§. 162, *& ſeq.*) Somebody will perhaps object that Fiſh have no Lungs, and yet they have very red Blood. 'Tis true, the Organs of Sanguification have a different Mechaniſm in Fiſh: In them the Heart lies in the Head, in a

ſort of Bag, with only one Cavity or Ventricle. A kind of Sacculus receives the Blood from the Vein below, which is inſtead of a Cava in Fiſh; which Sacculus contracts and conveys it to the Heart above, which next contracts and propells the Blood into an Artery or Aorta; the firſt Branch of which goes to the Viſcera, and the next dividing into two, ſends one of them to the Branchia or Gills, which are Cartilages dividing into a multitude of Arches under the lower Jaw, upon every one of which are extended Branches of this Artery in a reticular Diſpoſition. Theſe Gills in Fiſh are conſtantly moving both above and under Water, in the manner of Lungs, whoſe Office they ſupply; tho' their Motion is not ſo great as to generate Heat in the Blood, whoſe Parts are therefore more ellyptic than ſperical, and compoſed of but very few red Globules, or ellyptic Spherules. But the Blood of thoſe Animals which have neither Lungs nor Gills is without any Colour. So that this Objection from Fiſh is ſo far from oppoſing, that it confirms my Theory of Sanguification in the Lungs. But laſtly, ſomebody may ſay that the Blood in a Fœtus is red, tho' the Lungs are quieſcent. But then the Blood of the Fœtus is derived from its Mother, and ought till the Birth to be eſteemed a Part of her. If you anſwer again, that even the *Punctum ſaliens* in an *Ovum* is red; you urge an Objection the moſt difficult to ſolve. But we know from *Pitcairn* and *Bellini*, that the Air penetrates thro' proper Ducts in the Egg; and that if theſe Ducts are obſtructed and deprived of their Commerce with the Air, the Chick will not at all hatch or advance in Growth; and the Eggs of Silkworms will not hatch, even in a warm Place, if you keep them cloſe ſhut up from the Air in a Glaſs.

§. 201.

§. 201. If it be asked whether the ponderous and *elastic* [1] Particles of the Air mix with, or enter into the Blood in the Lungs, in order to produce vital *Oscillations* [2] or Vibrations by their Elasticity, according to *Borelli*; we answer, it is impossible for such elastic Particles to enter the Blood in the pulmonary Artery; nor have we any Reason to believe that such enter the Vein. But it will appear very probable that no such elastic Particles enter the Blood in the Lungs, if we consider the *Compression* [3] of the Veins by the Vesicles, when distended with Air, in Inspiration; the compressing Force of the *Thorax* [4] acting on the Veins in Expiration; the particular manner in which the pulmonary Artery opens or changes into the *Vein* [5]; the very difficult Passage that elastic Air meets with thro' small *Ducts* [6], which are easily pervious to *Oil* [7], Water, or Spirits; with the *lubricating Juice* [8] of the internal Membrane lining the Trachea; and the pernicious *Consequence* [9] of such Air when arrived into the Blood. But then may not the very subtle, vapory and attenuated Humours, discharged into the Vesicles of the Lungs by exhaling Arteries, be again *absorbed* [10] thence by patulent Orifices, and convey'd into the pulmonary Veins? This indeed seems probable; because even the ceraceous Injection of *Ruysch* passes thro' the Vein, and transudes into the Cavity of the Vesicles. However, the Air has been sometimes found,

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in a conſiderable Quantity, in the Heart, its coronary Veſſels and the larger Arteries, by *Sylvius* and *Ruyſch*.

[1] I ſay the *elaſtic* Parts of the Air; becauſe it is a Chaos or confuſed Mixture of the Particles of all Bodies: For in it we find (1.) Fire, which penetrates all Bodies, and therefore cannot be excluded from the Lungs. (2.) Exhalations, whoſe Quantities and Qualities are various and undetermined, and therefore do not come under our Conſideration of the Air's Efficacy with regard to Reſpiration. For the Air is freely reſpired by the Lungs, as well in the dry Countries of *Arabia* as in the marſhy ones of *Holland*. (3.) Water, which readily paſſes into the Air, but yet we breathe a cold and dry Air more eaſily than a moiſt one. (4.) Laſtly, the elaſtic Particles, concerning which our Queſtion is, whether they enter the Veins of the Lungs, mix with the Blood, and then exert their Elaſticity, to excite Oſcillations therein. But it muſt be obſerved, that the ſame elaſtic Particles become inelaſtic, and put on another Nature under different Circumſtances; for though theſe are compreſſible in the common Atmoſphere, and repell each other ſtrongly, in Proportion to their Contacts, yet, when interſperſed in the Parts of Liquors, they change their elementary Texture, become inelaſtic, and afford no Signs of their having any Spring, without the Application of Fire, Freezing, Effervеſcence, Fermentation; or laſtly, the removing ſo much of the atmoſpherical Weight as will reduce the Mercury in the Barometer from twenty nine to fourteen Inches Height. That the Air would thus enter into, and become permanent or fix'd in Liquors, was firſt demonſtrated to us by *M. Mariot*, who found this Air in all the Li-

quors

quors that he could try by Experiment; and has shewn that the Air will enter and fix itself in all Liquors till they are saturated with a certain Quantity, beyond which you cannot force them to take in any more Air. I some Years ago filled a long-neck'd Phial with Water, and forced out its included Air, in Form of Bubbles, by the Air-Pump; but upon leaving the same Water exposed to the Air for twenty-four Hours, it had absorbed as much Air as it contained before; and then, upon Agitation, and endeavouring to force more Air into it, there would not enter one Particle. In this manner the Air, embodied in our Aliments, passes with the Chyle into the Blood; but then it neither exerts any Elasticity, nor produces any Oscillation in the Liquors containing it; and, as the Air never passes in an elastic State into the Blood, it cannot there produce any of the Effects ascribed to it. But the Asserters of elastic Air entring the Blood in the Lungs, bring a capital Experiment to prove their Opinion; *viz.* they can, by the Pump force elastic Air out of the Blood, taken from the pulmonary Artery, and much more abundantly from the Blood of the pulmonary Vein; whence, say they, the Blood must have taken up a good deal of Air in the Lungs, as it passed from the Artery into the Vein. But they don't consider that their very Experiment makes this elastic Air out of inelastic Matter; and that we are from hence only assured, that the permanent or fixed Air is more easily extricable in an elastic State, from the Blood, after its Attenuation by the Lungs, than before: Therefore their Experiment does not demonstrate more Air in the venal than in the arterial Blood of the Lungs, only that it is more extricable in the former, as *Pitcairn* justly observes.

[a] *Borelli*

[2] *Borelli* obſerving that the Blood maintained its Fluidity in the Veſſels, and congealed after Extravaſation, endeavoured to account for the Phænomenon by an Oſcillation, or a contracting and dilating Motion in the aereal Particles, exciting an inteſtine Luctus in the Blood; for, ſays he, the Air being compreſſed by the Arteries in their Syſtole, will, by its Elaſticity, re-act and excite a vibratory Motion in the Particles of the Blood. His Hypotheſis, tho' too weak to need any Refutation, has yet been inconſiderately received by the *Italians* after him.

[3] When the Veſicles are diſtended with Air, by preſſing on the Veins the Blood will reſiſt the Entrance of elaſtic Particles; and if the Air found Admiſſion into them, it would not inflate the Lungs, but run into the Heart and Blood-veſſels.

[4] For then the Lungs are compreſſed by the Contraction of the Thorax, which expells the Air thro' the Trachea.

[5] As the pulmonary Artery and Vein are continuous to each other, without any intervening Cryptæ, or Cells and Ducts large enough to admit any of the Blood; there is no room for any Admittance of the Air here. But yet, as there are exhaling Veſſels in the Cavity of the Lungs, diſcharging an aqueous Moiſture; ſo there are alſo abſorbing ones that admit watery, infectious, and other Particles of the Air; and even by a ſtrong Inflation of the Lungs in the expiring Animal, before the abſorbing Ducts collapſe by Death, the Air itſelf will enter by them into the pulmonary Veins, and return to the Heart. But then, in a natural State, the Lungs never ſuffer ſuch a Preſſure as will force the Air itſelf into their Veins. Therefore no Air enters the Blood by the Lungs

but

but in a fixt or permanent State, as it enters and exists in Liquors.

6 Thus a Bladder taken out of an Animal will retain Air tho' it transmits Water; which is an Argument that there are Pores pervious to Liquors and impervious to Air. And Water being forced into the Lungs when they begin to putrify, will transude thro' the Pores of their Membranes; but as those Ducts are pervious to aqueous Liquors 'tis not likely they should admit Air, for Water resists Air; and therefore Watermen wet their Sails to prevent the Air from passing through their Pores, to make the greater Pressure. Add to this that the Air entring the Lungs will be resisted by a Mucus lining the Trachea, Bronchia, and Vesicles, so that it cannot pass through the Pores into the Blood-vessels.

7 Thus, in the Air-pump of Mr. *Boyle*, the whole Weight of the Atmosphere cannot press thro' the oiled Leathers interposed betwixt the Junctures; and it is very easy for the Air to pass through a Mixture of Oil and Water.

8 The bibulous Veins of the Bronchia always float in a viscid, mucilaginous Liquor, lubricating the internal Superficies of the Lungs; but the Air will not enter Ducts that are fill'd with a watery Liquor, and will be still more resisted by the glutinous Mucus.

9 For Air being forced into the Veins of an Animal, does, in a little time, obstruct the small Vessels of the Lungs, and cause a fatal Peripneumony; or else by endeavouring to make its way thro' Ducts that are impervious to it, it bursts them, and occasions sudden Death.

10 It is by these absorbing Orifices that watery Vapours are often highly serviceable in acute Diseases; and I know a Remedy which the Lungs thus

thus abſorb almoſt as faſt as a Sponge does Water; *viz.* the Fumes of warm Vinegar in a Peripneumony. It is alſo by this Abſorption of the Lungs that contagious Diſeaſes are communicated barely by talking with the Sick; and therefore a Phyſician ought never to viſit ſuch Patients when he is faſting, or his Circulation depreſſed, becauſe the Abſorption is then greateſt. But yet I do not think that the permanent Air, which we diſcover in the Blood, and make elaſtic by Experiments, is this way abſorbed; but enters with the Chyle from our Aliments, which are all of them, both ſolid and fluid, ſaturated with inelaſtic Air, which paſſes in that State thro' all the digeſtive or Chylopoietic Organs. This is alſo more likely than that the Air ſhould be convey'd into the Blood by inhaling Veſſels of the Skin, and exhaled again by the Perſpiracles of the ſame Emunctory. Laſtly, the ſtrongeſt Argument to prove the Air is not received into the Blood, is taken from the Experiment I before mentioned (*n.* 1.) that Liquors abſorb Air till they are ſaturated, and no longer; now if the Blood contains Air, as we know it does, it muſt be either ſaturated or not; if the laſt, the Blood in the Lungs will take in Air till it is replete; but then this Air no ſooner enters the Blood, than it looſes its Elaſticity, and becomes fix'd, as in other Liquors: But ſuppoſing the Blood to be already ſaturated, it can then abſorb no more Air in the Lungs, and if any be forced into them by Preſſure it will remain elaſtic and prove fatal. I ſhall now only mention one more Experiment that I made to determine the Point in Controverſy; *viz.* we know that by removing the Preſſure of the Atmoſphere by the Air-pump, the Stomach, Lungs, Bladder, or any other Part which contains ever ſo little elaſtic Air, will then ſwell; I there-

fore

fore ty'd up a Portion of the pulmonary Artery at each End, before it was cut out, and then put it into the exhausted Receiver, where it appeared to contain no Air, by not making any Intumescence. I did not think the Vein proper for this Experiment because of its absorbing Power.

§. 202. Whether or no the Blood is propell'd into the Lungs, and exposed to the Air there, to be *cooled* [1], and freed from its fulliginous *Fumes* [2], or to receive some *Spirit* [3]? Such has been formerly the Doctrine of the Schools; but without any Authority from our Senses, Anatomy, and Thermometers.

[1] The cooling of the Blood in the Lungs, proposed by the Ancients and revived by *Cartesius*, comes pretty near the Truth; for since the Atmosphere is always colder than the Blood in the Lungs, from which it is separated only by very thin Membranes, it must inevitably take off some of the Heat; which is also confirmed by a warm Air, equally hot with the Blood, being destructive to all Animals which have Lungs; and it is certain that the human Lungs labour more as the Air is warmer or the Blood hotter than usual, whether the latter proceeds from a Fever, external Heat, or muscular Motion. But tho' we allow that the Blood is cool'd, or communicates Part of its Heat to the Air in the Lungs, yet you must not imagine this to be the great Use of the Lungs, for it is only an Accident or Consequence from the Air; since the Lungs, considered in themselves, are so far from cooling the Blood, that by their Structure and Action they increase its Heat, as much or more than the Air abates

abates it, as appears from the Blood of the pulmonary Vein being warmer than that of its correſponding Artery.

2 *Galen* and the Ancients ſuppoſed that an innate Heat reſided in the Heart, by which the Blood was warmed; and that this Heat was fed or ſupported by a radical Moiſture, which it conſumed; whence proceeded thoſe Fumes or Vapours diſcharged by the Windpipe, as the Smoak of a Fire by its Chimney; and from hence too they deduced that Drought and Blackneſs of the Tongue and Mouth, obſervable in many acute Fevers. But this Blackneſs of the Tongue ariſes from a Stagnation and Corruption of the thick Juices in the exhaling Veſſels of this Organ; whence, if you ſcrape a black Tongue, the Blood generally follows. 'Tis indeed certain that no inconſiderable Quantity of Vapours are diſcharged by the Windpipe from the Lungs; but theſe in a healthy State are altogether aqueous, and partake neither of the Nature of Smoak, Fire, or any other malignant Quality; as is evident from its condenſing into meer watery Drops, when ones Breath is blow'd againſt a Looking-glaſs, from which the Moiſture will entirely evaporate again into the Air, without leaving any Reſiduum.

3 This Spirit, according to *Galen* and the Ancients, was received from the Air into the pulmonary Vein, by which it paſſed into the left Ventricle, and there imparted that vital Faculty to the arterial Blood, as enabled it to run into all Parts of the Body. 'Tis certain that elementary Fire, and all other ſubtle Bodies in the Air, do enter into, and mix with the Blood in the Lungs; but then this is no more than what happens in common to the whole Superficies of the Body, in which there is not a ſingle Pore that can exclude the moſt ſubtle

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Corpuſcles in the Air; which being the common Medium of Bodies, reduces them to the ſame Temperature; and I have in my Chemiſtry demonſtrated that at one and the ſame Time, the Thermometer ſhews that Gold, Snow, and Wool have the ſame Degree of Cold.

§. 203. *Sylvius*, and many of the Chemiſts, have taught, that the Blood becoming almoſt boiling or ſcalding by a hot *Effervescence* [1] in the right Ventricle of the Heart, was drove from thence into the Lungs to be there extinguiſhed, cool'd, and condenſed by the cold and nitrous Quality of the Air; but this their Hypotheſis is contrary to Experience. Others have thought that a ſubtle *Nitre* [2] of the Air was mix'd with the Blood in the Lungs, to give it a florid or purple Colour; of which Opinion was the eminent Dr. *Lower*; but even this Hypotheſis is not much more conſonant to Truth and Experience. In the mean Time it is certain, that the Air communicates or performs ſomething more in the Lungs than what we have yet diſcovered; for if it be not perpetually *renew'd* [3] it kills the Animal, not from its being heated, rarified, or condenſed, but from ſome other latent Change: *Query*, Whether it is not from the Deſtruction of its Elaſticity? and whether this is not the ſecret Pabulum of Life in the Air, ſo much talked of by the Alchemiſts? Laſtly, It may be aſk'd, why a Perſon cannot breathe under Water, but is quickly *ſuffocated* [4], notwithſtanding

ing the Thorax and Lungs remaining capable of an alternate Contraction and Dilatation, by a Continuance of the ſame Cauſes, might ſeem to have the ſame Action with the Air? This is no eaſy Queſtion [5].

[1] We have before ſhew'd that the Blood cannot receive any ſuch Heat or Effervescence, neither from any Fire of the Heart, nor any Ebullition of the Blood with an acid Chyle, nor with an acid Lymph and Spirits. Vide §. 164 and 18.

[2] This was the Syſtem of *Lower* and *Mayow*, after they had diſcarded the *Biolychnium*, or *Flammula Vitalis* in the Heart, ſuppoſed by *Willis*. Thoſe Gentlemen obſerving that the Blood in the pulmonary Artery was of a dark red Colour, and of a bright Scarlet in the Vein, inferred that it muſt have acquired that Height of Colour in paſſing the Lungs; *Lower* again thought that it muſt be derived from the Air in Reſpiration, becauſe the Blood will be thus florid even by one Inflation of the Lungs, but not at all if the Windpipe was ty'd. This they thought was the more probable, and even demonſtrable, from the Surface of extravaſated Blood looking florid, whereas at Bottom or Withinſide it looked black, as having had no Contact with the Air; but even the Bottom, after it had been expoſed to the Air, became equally florid with the Top; from all which they thought it apparent, that the florid Colour of the Blood aroſe from the Air; but in the Air they found nothing ſo likely to produce this Effect as a volatile Nitre, ſince this Salt floats in the Air, and will alſo make Fleſh look of a red Colour. But I object, (1.) that Nitre is a Salt not volatile with leſs than 230 Degrees of Heat, and the Air

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is hardly ever so hot as 90, nor is it properly Nitre that floats in the Air but a volatile Acid, which, by meeting with earthy and inflammable Particles, becomes a neutral Salt or Nitre. (2.) It is not the Property of Nitre only to change the Blood florid, but most other saline Substances will do the same, as common Salt, Borax, Tartar regenerated, *Venice* Soap, *&c.* Add to this, that the venal Blood will appear equally florid with the arterial, only by a brisk Agitation, and after letting it stand still it will become black again. (3.) We are convinced that the Blood becomes more florid barely by increasing muscular Motion; and every Farrier knows what a Difference there is in the Colour of a Horse's Blood that has been a long Journey, and one that has rested a long time in the Stable. The Blood of a cachectic Woman is very watery, and of an obscure red; but by increasing the Blood's Motion with Frictions, Exercise, and Medicines, it recovers its bright Colour again by degrees; whereas without those means it would have continued in its first impoverished State. Some may object, in behalf of Dr. *Lower*, that these means will quicken the Course of the Blood thro' the Lungs, which will therefore impart more of the Air's Efficacy; but this will be little more than a Subterfuge: And we have before demonstrated that the Lungs conduce more to the Redness of the Blood than all the Muscles of the Body (§. 200. n. *ult.*): And (4.) we also demonstrate (§. 200 and 226.) that the red Colour of the Blood does not arise from any Salts, but by the Combination of the pellucid and serous Globules, by Sizes into the larger red Globules, which Combination of the Globules is effected more by the Action of the Lungs than of the Arteries and Muscles, but not at all by any nitrous Salt of the Air. (5.) In-

ſtead of proving, it is begging the Queſtion, to ſay that this Appearance of the Blood ariſes from the Abſorption of an aereal Nitre in the Lungs, when we find the ſame in Fiſh which neither breathe nor have Lungs; and yet their Blood is ſufficiently red, tho' no Proof can be made of any Air being abſorbed from the Water which paſſes thro' their Gills. It muſt indeed be owned, that Fiſh have a Bladder of Air, by contracting or dilating which they can either riſe or fall in the Water, and ſometimes emerge above its Surface; but then no Communication can be demonſtrated betwixt this Air-bladder and the Gills, even by the Confeſſion of M. *Du Verney*, who perſuades himſelf that the Gills attract Air.

3 It is an extraordinary Experiment in Pneumatics, that convinces us no Animal can ſurvive long by breathing the ſame Air that has once entred the Lungs, unleſs freſh Air be continually ſupplied to it. For a Bird being included in a Glaſs with a Thermometer, having no Commerce with the Atmoſphere, vomits and dies in leſs than an Hour, without cauſing the Thermometer to aſcend: And therefore it cannot proceed from the Air being over-heated by the Bird; nor can it be from any venomous or noxious Vapours, ſince none ſuch can be proved or demonſtrated in the Air we have once breathed. What then have we in the confined Air to account for this, but the Deſtruction of its Elaſticity, whence it will not be able to diſtend the Lungs, nor maintain Fire or Flame, *&c.* But not only Animals, but even all the Ova, both of them and Vegetables, require a free Commerce with elaſtic Air to become prolific, which Elaſticity they deſtroy, and therefore require a Succeſſion or Renovation of ſuch Air: Is not this therefore the occult Pabulum of Life, or the Bird of *Hermes*,

Hermes, ſo obvious to all, and yet ſo long concealed from Mankind. I before obſerved to you that the Eggs of Silk-worms will not hatch, even in a warm Seaſon, while they remain ſhut up in a Bottle.

4 When a Perſon is under Water 'tis evident he cannot let the Air into his Lungs, tho' he may expel moſt of the Air that is in them; neither will Water be admitted either thro' the Glottis or the Gula, ſince they will be cloſed by Initinct, or an inconſcious Contraction of their Muſcles; but without an alternal Contraction and Dilatation of the Lungs by Reſpiration, the Blood cannot paſs thro' them from the right to the left Side of the Heart (§. 200.); the Blood will then be urged into the pulmonary Artery till it reſiſts the right Ventricle, which will then be unable to empty itſelf, and remain diſtended, while the pulmonary Vein and left Ventricle, not receiving their Blood as uſual, will remain flaccid and unactive; in the mean time the Aorta and all its Branches will contract and force their Blood into the leſs reſiſting Veins, whence the Cava and right Auricle will be diſtended for want of a Paſſage to the Blood thro' the Lungs, and therefore Suffocation enſues, or the Blood's Motion ceaſes. And thus it alſo is with People who are hang'd; only in them there is a Compreſſion of the Brain alſo, or an Apoplexy, from the Cord obſtructing the jugular Veins.

5 We muſt not here omit the famous Experiment of Dr. *Hooke*, deſigned to prove that the Blood may paſs through the Lungs without their alternate Dilatation and Contraction. This Gentleman laid bare the Windpipe of a live Dog, whoſe Thorax was opened, and by blowing into the Lungs with a Pair of Bellows, he found that the

dying Animal by this means came to Life again, and continued alive, though the Lungs were only kept distended with Air by the Bellows; whence he concluded that the Blood passed freely through the Lungs tho' they were quiescent. But we must observe (1.) that the Dr. confesses his Experiment would not hold long without repeating the Inflation; and (2.) that he made several Incisions in the Lungs that the Air might pass freely thro' them without stagnating; and therefore the Experiment is no ways conclusive.

§. 204. But we know both by Causes and Effects, that the Chyle is rather *confusedly* [1] than perfectly mixed in the right Ventricle of the Heart; and that in the left Ventricle they appear more intimately combined: We also know that when the *Lungs* [2] are strong they duly perform every Thing mentioned at §. 200. but when they are weak or impaired, their Effects on the Blood and Chyle are much more imperfect.

[1] The Blood of the right Ventricle neither appears so uniform nor florid as in the left, and *Lower* tells us he has sometimes found curdled Milk in the former, but never in the left Ventricle or in the pulmonary Vein; whence it follows, that the Chyle and Blood are most intimately mixed in the Lungs.

[2] In general the Combination and Solidily of the Parts of the Blood arises from the Action of the Arteries and Muscles; but their Attrition is much greater in the Lungs than in any other Part of the Body, since the same Quantity passes in the same Time thro' the Lungs as thro' all the other Parts; whence

whence it happens that when the Lungs are weakened, ſcirrhous, eroded, ulcerated, conſumed, or attached, Sanguification is much impaired, the Blood is more watery, and the Cruor leſs than it ought to be. Hence in conſumptive People the Chyle is neither aſſimilated nor the Blood compacted, but the Globules of the laſt ſeparate into ſmaller, till they run through the ſmall Ducts of the Skin in form of Sweat; and as this Action of the Lungs is analagous to that of Muſcles, ſo it can be only compenſated by gentle Exerciſe and riding on Horſeback, or in a Coach upon the Stones, whereby the Blood and Chyle receive the ſame Attrition in the Veſſels as they ought to have in the Lungs.

§. 205. After the Blood has received the Impreſſion of the Lungs in the ſmalleſt Arteries, it flows from them into the enlarging Veins, where being leſs preſs'd, and urged with contrary Motions, it does, by the Elaſticity of its Parts, expand and rarify a little, whence becoming more frothy, red and florid, it paſſes into the left Auricle and Ventricle.

§. 206. By paſſing into the left Auricle, though much leſs than the right, the Particles of the Blood are again mixed in ſome Degree, and prevented from ſeparating into different Sorts, or from running into Coheſions (as *per* §. 163.): But as the Blood is here more fluid and leſs liable to Concretions than before its ſwift Propulſion through the Veſſels of the Lungs; therefore the left Auricle

is both *leſs* [1] in Size and more ſimple in its Fabric than the right.

[1] The Smallneſs of the left Auricle is compenſated by the Largeneſs of the left Sinus, which is as much larger than the right Sinus, as the right Auricle is larger than the left; ſo that each Auricle and Sinus taken together, are equally capacious to receive and retain the Blood while the Ventricles are in their Syſtole. But the left Auricle is much weaker and ſmoother than the right, becauſe the Blood having been but lately attenuated in the Lungs does not want to be farther divided by the muſcular Threads, neceſſary for the more crude and ſlowly moving Blood of the Cava.

§. 207. The Blood and Chyle thus arriving in the left Ventricle of the Heart with little or no ſtaying by the way; is then, by the contracting Power of the ſame Ventricle, ſwiftly and ſtrongly propell'd into the Aorta, and by thruſting forwards the preceding Blood moves the whole Maſs.

[1] The left Ventricle expells about two Ounces of Blood into the Arteries at each Syſtole; but the Arteries being full, the Aorta muſt dilate ſufficient to receive that Quantity, which Dilatation proceeds inſtantly throughout the whole arterial Syſtem, driving forwards the preceding Blood by that which follows; hence the Force of the Heart ſeems to be ſpent on the Arteries only, and not to be extended to the Veins, which are fill'd by the Contraction of the Arteries; which laſt do, in each Syſtole, diſcharge into the Veins ſomewhat

leſs

leſs than the two Ounces they received from the Heart.

§. 208. The Action of the Lungs is therefore of greater moment in a healthy Body than that of any of the other Viſcera; ſince there is not any one Part of the Whole that receives ſo much as a ſingle *Drop* [1] of arterial Blood till it has been firſt exquiſitely *ſtrained* [2] through the Lungs: It alſo appears, that the whole Maſs of Juices in the Body paſs thro' the Lungs *in the ſame Time* [3] that they compleat their Circuit thro' all the other Parts; ſo that while all the other Viſcera receive only a ſmall Portion of the Blood, the Lungs receive and tranſmit the whole Maſs: Hence we diſcover the Lungs to be the principal Elaboratory of Sanguification, and for converting the Chyle, which is all brought hither, into *nutritious Juices* [4]; in this Organ the whole Maſs of Juices receive that Degree of *Fluidity* [5] and Attenuation which fits them to circulate freely through all the ſmalleſt Veſſels, and which they cannot receive in any *other Part* [6]; and it is therefore here chiefly that the Blood and its Juices are prepared and fitted to make the ſeveral *Secretions* [7], and to perform all the Actions of Life and Health which depend on the Efficacy of the Fluids [8].

[1] Even the Heart and Lungs themſelves do not receive any arterial Blood for their Nutrition but what has been firſt ſtrained through the vaſcular Plexus of the Lungs. The Heart, as a Muſcle, receives

receives its Blood from the coronary Arteries in its Basis; but these arise from the Aorta (§. 183.) which receives all its Blood from the left Ventricle after it has passed through, and suffer'd the Action of the Lungs. And the Substance of the Lungs themselves are not nourished by any of the pulmonary Arteries, but by the bronchial Artery of *Ruysch*, which always arises either from the Aorta or some Branch of it, as the Subclavian, or Intercostal. In short, no Blood is fit for Nutrition, or disposed to pass thro' the several Series of Vessels, but what has lately received the Action of the Lungs.

2 All the Blood of the right Ventricle passes into the pulmonary Artery (*per* §. 155.) and all the Blood of the pulmonary Artery is received into the Vein of that Name (*per* §. 198.); but all the Blood of the pulmonary Vein goes into the left Ventricle of the Heart, and therefore it is from thence only that the whole Body is supplied with arterial Blood by the Aorta and its Branches. 'Tis true, the Ancients were of Opinion that some of the Blood transuded from the right to the left Ventricle through the muscular Septum of the Heart; but this Opinion, which was refuted above two Centuries ago, seems to have proceeded from their observing and mistaking the *Foramina Thebesii*, or small venal Orifices in the right Ventricle.

3 The right Ventricle propells its two Ounces of Blood into the pulmonary Artery in the same Instant in which the left throws its two Ounces into the Aorta; and therefore two Ounces of Blood must pass thro' the Lungs in each Perisystole or Interpause betwixt every Dilatation and Contraction of the Aorta; otherwise the Aorta would not be supplied with Blood enough from the left Ventricle to be forced into and distend its Branches. It

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is therefore hence apparent that the pulmonary Artery must receive as much Blood as the Aorta. Computing then the Mass of Blood to be twenty Pounds in a healthy Man, whose Pulse beats 3,600 times in an Hour, as the Heart ejects two Ounces at each Systole, the whole Mass of Blood will then circulate thro' the Heart and Blood-vessels thirty times in an Hour, and therefore the same twenty Pounds of Blood must pass thirty times in the same Space of an Hour through the Lungs of such a Man, whereas in Women and Children the Pulse is still more frequent. But if the Blood's Course be accelerated, either by muscular Motion or otherwise, the Lungs will then transmit proportionably more Blood in the same Time than before; from whence their Efficacy in changing the Blood appears to be (*cæteris paribus*) equal to that of all the other Parts of the Body besides; since neither the Brain, Liver, Spleen, Muscles, or any other Viscus, has any Blood but what comes from and through the Lungs. Add to this, that the Force or Action of any of the other Viscera besides the Lungs, is partly employ'd in preparing some Juice for the common Service of the Body; but the Lungs act wholly on the Blood and Chyle, without spending their Force in secreting or elaborating other Juices.

4 From the Chyle only are supplied the vast Quantity and different Sorts of Juices which we daily lose or discharge by Perspiration and the other Excretions; but in order for the Chyle to become nutritious, it must first change its own Nature and put on that of Blood; for without this Change our Blood would be quickly consumed, and we should have only a watery Chyle circulating in our Vessels. But our nutritious Juices are taken into the Blood either immediately by the bibulous

bulous Orifices of the abſorbing Veins which open into the Cavity of the Mouth, Stomach, and Inteſtines, or elſe round by the common Courſe of the lacteal Veſſels, and is then forced all of it through the Lungs, with the venal Blood, before it paſſes to any one Part of the Body; ſo that many Parts of the Chyle may often circulate or become nutritious, and perform all their Offices without ever touching or entring the Liver, Spleen, or any other one particular Viſcus; whereas none of thoſe Particles can make one Circulation without entirely paſſing through the Lungs. It therefore follows, that the Chyle is as much changed or prepared for Nutrition by the Action of the Lungs only, as by the Actions of all the other Parts and Viſcera in the whole Body. Phyſicians ought therefore to have a very particular Regard to the Lungs in all Diſorders whatever; ſince no one Malady can happen without affecting them more or leſs, and ſince Health, or the due Performance of all the Functions in the Body, depending on the Blood and Juices, ariſes chiefly from this Spring.

5 There are two great Cauſes of that Degree of Fluidily obſervable in the circulating Blood; one is the Minuteneſs of the abſorbing Orifices by which the Chyle is taken up and convey'd thither; and the other is the conſtant Attenuation of them both by the Action of the Muſcles and Lungs, but chiefly of the laſt, which receives vaſt Quantities and never ceaſes to labour.

6 Becauſe in the Lungs, the reticular Plexus of the pulmonary Blood-veſſels, ſpent on the Veſicles, receives an additional Agitation and Preſſure from the Weight and Elaſticity of the Air, which inflates them, and does not act in that Manner on the Blood-veſſels of any other Part of the Body.

7 We

7 We before obſerved (§. 198.) that it is probable the Lungs have their Blood-veſſels divided into the ſame Number of leſſer Series as thoſe in the other Parts of the Body; from whence naturally follows, that a Diſpoſition or Aptitude is here received by the Parts of the Blood, to form the Secretions, and paſs freely through the ſmaller Series of Veſſels in the ſeveral other Parts of the Body. For preparatory to Secretion, it is neceſſary for the Blood to contain a ſufficient Number of the Globules of all Sizes, as well of the larger red, and ſerous ones, as of the many ſmaller and pellucid or lymphatic ones, that every Series of the Veſſels may receive their adequate Globules; or that while the larger red Globules are paſſing on through the ſanguiferous Artery into the ſanguiferous Vein, the ſmaller ſerous Globules may paſs off laterally into their leſſer lymphatic Arteries, of all the Orders. For without Juices adequate to paſs the Sizes or Diameters of the Veſſels, thoſe Veſſels would be uſeleſs, and the Parts they compoſe become incapable of their Actions; and even the Nerves would be all uſeleſs without a Supply of Globules ſmall enough to pervade their minuteſt Tubuli. But the Lungs make all the different ſized Globules of the Blood, not only by dividing the larger into ſmaller ones, but alſo by moulding or wire-drawing each of them through its ſeveral Series of Veſſels, adequate to the Diameter of each Set of Globules. But the Lungs do not only generate or frame each Set of Globules, but they alſo compact and poliſh them, ſo as to increaſe their ſpecific Gravity beyond that of Water: And how eſſential the ſpecific Gravity is to the determinate Nature of every Body is obvious to all; for could we make Mercury 19 times heavier than Water we ſhould not be far from making it Gold.

8 All

[8] All this is to be underſtood of the Lungs in an Adult; for in the Fœtus, whoſe Lungs receive no Air, no more Blood paſſes through them, in Proportion to their Bulk or Number of their Veſſels, than thro' any other Part of the Body; and therefore the Action of the Lungs on the Blood, which we have been here deſcribing, does not take place in the Fœtus.

§. 209. All theſe Effects (§. 208.) follow from the determinate Nature of the Blood and Chyle, from the known Fabric and Action of the Lungs, and from the determinate Force of the Heart, with the known Preſſure of the *Air* [1], acting as a heavy and elaſtic Fluid, firſt on the Air-veſſels of the Lungs, and by them alſo on the Blood-veſſels.

[1] Thus you have all the Effects of the Lungs, enumerated in §. 208, and explained by their Fabric and the Action of the Air in §. 200, beſides which, we require no other Cauſe to account for their known Effects or Appearances.

§. 210. What Occaſion have we therefore to ſuppoſe any Mixture of the Air, or an aerial Ferment with the Blood in the Lungs? If you aſk, whence comes the Air diſcovered ſeveral Ways in the Blood? We anſwer, from the ſame Cauſe by which it enters into all other Liquors, *i. e.* by Attraction or Abſorpſion. But if your Queſtion is, Whether it has any Action, as Air, in the Blood? we anſwer, that no ſuch Action of it ſeems probable there, unleſs its ſmall Particles reſume their Ela-

Elasticity, and run together into little Bubbles.

§ 211. Lastly, To what else, than the preceding Action of the Lungs, can we chiefly ascribe that Change in our Aliments which makes them nutritious, or of an animal Nature, capable of yielding an acrid and *volatile* [1] Salt? This Change or Volatization was indeed long ago observed by *Helmont*, who also derived it from the Action of the Air, but not in a just manner. Upon this Subject, the Lungs, you may peruse the Writings of *Bellini* and *Pitcairn*, with those of *Malpighi*.

[1] Every Animal either lives immediately on Vegetables, or else feeds on the Animals which themselves feed on Vegetables; (*Vid.* §. 95. N°. 11.) but vegetable Substances do all afford a fix'd alcaline Salt by Fire, whereas all animal Substances yield a volatile alcaline Salt. But these fixed Salts are volatilized in the animal Body; for in the Urine and Fæces of a Maid who had the Green-sickness, and took, by my Order, two Drachms of fixt Salt daily, no other than valatile Salts was found. And the little graniverous Bird we call a Sparrow, though fed on vegetable or acescent Substances, that yield a fix'd Salt by Fire, affords none but volatile Salts by Distillation, nor can any other Salt be had from its Dung. This Change or Volatization was, by *Helmont*, judged to arise from the Air, because he had observed that a fix'd Salt exposed to the Air melted or dissolved, and that by drying it at the Fire, and then exposing it to the Air again, for ten Times successively, it at last became volatile, and wholly exhaled into

into Vapours, leaving an Earth. But we derive the Volatization and Change of Vegetable into animal Substance, barely from an Attrition of their Parts; for if any Plant, yielding only an Acid and a fix'd Salt, be laid in a Heap, it putrifies, not without growing so hot as to be almost intolerable to the Hand; now we know that Heat always arises from Attrition, and therefore Attrition is the Cause that renders fix'd Particles volatile. But the alimental Juices in the human Body suffer the greatest Attrition in the Lungs (*per* §. 200 and 208.) and therefore it is by them chiefly that the fixed Particles are volatilized, and those of Vegetables changed into animal Substance.

Concerning the Action of the Arteries or their contained Fluids.

§. 212. IN order to understand what further happens to the Blood and Chyle, now moving forwards in the Aorta and its Branches, we ought to be previously acquainted with the Principles and Laws of Hydraulics, by which all Liquors, moving with a certain Velocity through known Vessels, are determined in their Courses or Directions towards particular Parts; but to demonstrate these Laws of Motion in Fluids, to which all Liquors are subvervient in their passing through Vessels of any kind, is the Business of *another Place* [1], or rather the Province of Mechanics.

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The ſeveral Velocities, with which our Juices move through their Veſſels, are eſtimated from the Cauſes and *Effects* [2] of thoſe Velocities, obſerved either by our Senſes, or diſcovered by juſt Reaſoning. But the Structure and Action of the *Veſſels* [3] themſelves, containing Blood and Juices in Motion, are diſcover'd either by Senſe and *Reaſon* [4], aſſiſted with Microſcopes and *Injections* [5], or by the following Rule of Analogy, *viz.* that in the human Body you may judge of the inviſible Parts by thoſe which appear viſible.

[1] To become a Proficient in Phyſiology, one ought to be not only well acquainted with Mathematics and Mechanics, or the Doctrine of Quantity and Motion in general; but alſo to underſtand the Nature and Action of the Arteries, and of the Blood moving through them. In order to this we may obſerve, I. That in all Bodies there is a certain *Vis* or Power by which they generate Motion, and is reducible to the following Heads: (1.) The *Vis inertia*, by which all Bodies endeavour to remain in the ſame State, either of Reſt or Motion; (2.) the *Vis Gravitatis*, or Gravitation, by which Bodies tend towards the Center of our Earth; both which Powers are always proportionable to the Quantity of Matter in any Body, becauſe they are equally diffuſed throughout all the Particles of Matter, and therefore one Body that is twice as heavy as another will require double the Force to move it, and will retain its Motion twice as long. II. The *Extenſion* and *Figure* of a Body has a vaſt Influence on its moving Power; for a Body that is the moſt compact, or has the leaſt Surface, will ſtrike with the great-

eſt Force, and be moſt retentive of Motion. And even Gold itſelf, that is nineteen times heavier than Water, may be made to ſwim in that Liquor, by only beating it into Leaves with the Hammer. III. The Power of *Elaſticity*, peculiar to ſome Bodies only, by which they give way to any Force or Preſſure, and return again when the Preſſure ceaſes; this Power alſo enables Bodies to multiply or return the Motion firſt received. IV. The Structure or *Mechaniſm* in the Parts of a Body, by which the ſame Matter may be enabled to give different Effects and Appearances, not explicable by the general Laws of Matter and Motion alone; as when the contrary Forces of Gravity and Magnetiſm are oppoſed to each other in a Machine. V. The *Vires monadicæ* of Bodies, by which they attract and repell each other electrically or by Magnetiſm, a Power independent of Gravity, and not yet accounted for by any one. Beſides theſe, one that would explain the Action of the human Body muſt take into Conſideration (1.) the anatomical Structure of the Arteries (§. 132.); (2.) the intrinſic Nature of the Blood, and that which it acquires by Motion from the circumambient Parts: (3.) The Elaſticity and *vis inertia* of the Veſſels: (4.) The Gravitation of Liquors, and their Tendency to an Equilibrium: And (5.) the hydraulic Powers ariſing from the Veſſels and Liquors conjunctly. By theſe we are taught that a Liquor moving through a Tube or Veſſel, every where of an equal Diameter, meets with no Reſiſtance from the Sides but that of Friction; but in a Tube whoſe Diameter or Section is continually leſſening, the Reſiſtance of the Fluid gradually increaſes, and is greateſt where the Section of the Veſſel becomes ſmalleſt, *i. e.* at the Apex of the converging Cone, whence the Liquor being urged on in

diſtractile

distractile Vessels of this Figure, will distend or dilate them; but in Vessels gradually diverging, both the Resistance and Friction of the Liquor continually lessens. Lastly, (6.) the Action or Force of the Arteries ought to be considered; but in this great Caution is required; as may appear from the Attempts of some to compute the Force of the Heart from the Quantity and Height of the Jet of Blood flowing in a given Time from a wounded Artery in a Dog or an Ox; but in this Estimate they did not consider, that the Force or Velocity of the Jet is lessen'd, as well by the Wound of the Artery, as from the Diminution of the Impulse of the Blood to the Cerebellum. But the Misfortune is, that such physiological Subjects are usually handled either by Mathematicians unskilful in Anatomy, or by Anatomists who are not versed in the Mathematics.

2 As we know by Experience that the Heart contracts 3,600 Times in an Hour, and throws twice as many Ounces of Blood into the Aorta in that Time, we could easily compute the Velocity of the Blood, did we but know its determinate Quantity circulating in the Body: For the Velocity or Quantity of Motion in any Body is always in Proportion to its Weight and the Space it runs over in a given Time. But the Degree of the Blood's Velocity may be also discover'd by its Heat, which increases in Proportion to the Strength and Frequency of the Pulse, or Systole of the Heart. And thus it is even with all other Bodies, having any Contact or Friction of their Parts; for then they heat in Proportion to the compressing Force and the Velocity of their Motion.

3 The State of the Vessels is a material Consideration, whether they are rigid, like wooden Tubes, or ossified Arteries, or whether they are elastic and

diſtractile, like our Blood-veſſels in their natural and healthy State. In the rigid or immoveable Tubes, we are taught by *M. Amontons*, that the Fluid has no other Action on the Veſſel, nor the Veſſel on the Fluid, but that of Friction. Some of our Arteries and Veins are not equally diſtractile, from their being ſeated near reſiſting Bones or Cartilages, like the carotid and vertebral Arteries; nor in theſe do we obſerve more than a reciprocal Attrition betwixt the Fluid and Veſſel. Theſe diſtractile Veſſels are again either converging, as the Arteries; of the ſame or an equal Diameter, or elſe diverging, as the Veins, *per* §. 132, and *ſeq.* The Blood meets with a Reſiſtance, continually increaſing in the converging Veſſels, but only from Friction in the cylindric ones, and continually decreaſing in the diverging Veſſels. Laſtly, the Liquors themſelves are to be conſider'd; for if theſe are at reſt, they act only by their Weight, but if they are in Motion, they will act equally on every Point of the Veſſel, and be equally repelled again from every Point of the ſame Veſſel. The ſmoothneſs of the Arteries within-ſide, and the globular Texture of the Blood, prevent the Friction from being too deſtructive; but then the Glutinoſity of the laſt, and the Elaſticity of both, excite that Attrition which renders the Blood warmer than other Liquors.

4 Dr. *Herman* has demonſtrated that a right Line preſſed equally on every Side will form a Circle; and thus a Bladder being placed betwixt two concave Hemiſpheres, and fill'd with Water, will be diſtended into a Sphere: But as our Arteries are diſtended by the Parts of the Blood, impell'd and acting in all Directions like the Radii of a Sphere, therefore they are always circular; tho' the Caſe being otherwiſe in the Veins, many of them

them are triangular, oval, or variouſly figured. But the Arteries are ſo retentive of their Sphericity that, rather than part with it, they make ſemicircular Excavations in the hard Bones of the Skull; for the ſoft Bones of the Fœtus have none of thoſe *Sulci*, but as they grow up, the Expanſion of the Artery exceeding the Force of Accretion or Growth in the Bone, makes an Impreſſion by obſtructing the ſame where it ſtrikes.

[5] The Inflation of Air into the Veſſels, which is one kind of Injection, was known to *Galen*; but *Euſtachius* ſeems to have been acquainted with a more perfect Method of injecting, from the great Exactneſs with which he has traced the Veſſels, *Vid.* §. 134. But the firſt who brought ceraceous Injections into anatomical Uſes was the induſtrious Dr. *Swammerdam*, and the celebrated *Ruyſch* has carried the ſame to the higheſt Perfection, demonſtrating by his Injections that the ſmaller and inviſible Veſſels are like the larger and naturally conſpicuous ones.

§. 213. An Artery then, deſcribed in §. 132, dilates or *expands* [1] by the diſtending Impetus of the Blood, and when that Impetus ceaſes, by its Elaſticity it naturally contracts or *returns* [2] to its former Capacity; for if the Finger be thruſt therein, it forcibly compreſſes the ſame, and again contracts itſelf when the Finger is withdrawn. This Veſſel therefore appears *full* [3] of Blood in the living Animal, but is found very *ſmall* [4] and almoſt empty in a dead human Body, even tho' none of the Blood was loſt; it alſo reſiſts Inflation, forcibly *repelling* [5] the Air that is drove in, and

contracting to its leaſt Diameter, it then *ſtops* [6] or ſtands ſtill; ſo that the contractile Power of this Veſſel ariſes from the elaſtic Nature of all its component *Fibres* [7], as well from the moſt ſimple and minute as from the more complex Fibres, formed out of the preceding, or by ſome of the ſmaller Veſſels concreting with their inſpiſſated Juices; and laſtly, from a Repletion of the ſmall *Veſſels* [8] ſpent on the conſtituent Membranes of the Artery itſelf.

[1] The contractile Force of the Heart overcomes the Reſiſtance of the Aorta, and by that means throws as much Blood into the latter, as itſelf received from the venous Sinus: Thus the Arteries will be expanded every way, in Proportion to the Quantity of Blood received; but they will not dilate ſo much longitudinally as laterally, becauſe the reſiſting Bones determine their Length, the Arteries being full and coneide, the Blood will ſtrike in Lines perpendicular to their Sides, which will therefore yield.

[2] The Arteries are elaſtic Tubes (*per* §. 132.) but Elaſticity is the Property of Bodies by which they recover their former Poſition, when diſplaced by any Force; as when a tenſe Chord is forced out of its rectilinear Poſition ſo as to form an Arch or Angle, whoſe Periphera is always greater than a right Line: So that by this Extenſion the Particles of the Chord will recede from each other's Contact in that Proportion which the Arch or Angle bears to a right Line; but when the diſtending Force ceaſes, by the Attraction of Coheſion in the Particles, they will run into larger Contacts, and ſhorten the Chord, by reducing it to a

right

right Line. 'Tis in this manner that all the Arteries act; for the Sides of these being circular, they are distended, in every Point, by the Impulse of the Blood from the Heart, into larger Circles; but that Impetus from the Heart ceasing (*per* §. 185.) each elastic Circle or Segment of the Artery will return or contract, and propell the Blood as well towards the Heart as the Extremities; but the Resistance being less towards the last, by their opening into unresisting Veins, it passes only that way. This contractile Force in each Artery is, *in general*, stronger as it is nearer to the Heart or Basis of the Aorta; for there the Coats are strongest, and the Dilatation greatest, to which the Restitution must be always proportionable. I say in general, because there are some Arteries near the Heart, much weaker than others, more remote; as the Coronaries, Intercostals, *&c.* Hence every Circle or Segment of the Aorta and its Branches seems to act successively, propelling the Blood from the greater to the less resisting, but so swiftly as to be imperceptible to us in the Pulse.

3 The Arteries are always full; even in their Systole they are equally full, though they then contain less Blood than in their Diastole; and upon opening a living Dog the vibrating Aorta appears larger as the Animal has more Life, and acquires a smaller Diameter as he is nearer Death. In consumptive People there is often no more than a few Ounces of Blood in their Vessels, to which small Quantity the Arteries gradually contract and adapt themselves, so that they become almost imperceptible and like small Threads, the Skin at the same time adhering to the Bones; and yet there are here none of the solid Fibres consumed, except those destroy'd by Putrifaction in the Lungs. And in the same manner do the Arteries also con-

tract themselves to the wasting Juices in many other lingering Disorders. But were the Arteries to be so much evacuated of a sudden, they would not contract to so small a Diameter, and at the same time press with Force enough on the Blood to make it perform all its necessary Functions; thus the Impulse of the Blood to the Cerebellum being diminished, from whence the Heart receives its Force, a Deliquium or Death would ensue, even though but a small Part of the Mass were exhausted, from a Person of lax Vessels. Hence too, you may perceive the Insufficiency of the Method proposed by Dr. *Keil*, to estimate the Velocity of the Blood by the Distance to which a certain Quantity flies in a given Time from a wounded Artery of a known Diameter; for in this Experiment the Action of the Cerebellum is first gradually diminished, and then the Force of the Heart likewise, on which the Experiment is founded.

[4] In the dead Animal the Arteries appear small or contracted, white, with little or no Blood in them; because by their greater contracting Force they protrude their Contents into the less resisting Veins; therefore the Blood of the dying Animal will be chiefly accumulated in these last, which will appear turgid.

[5] It resists Inflation with the same Force that it resisted the Impulse of the Blood in the living Subject; and repells the Air again as forcibly as it propell'd the Blood in Life; because in its Systole it returns to its first small Diameter; otherwise the Artery would continually enlarge at each Diastole, as it does in the Formation of an Aneurism, or after a Wound.

[6] For a circular Fibre can never contract itself so as to have no Cavity, but only till its constituent Elements, or solid and earthy Particles come

into

into the closest Contact, for they cannot enter into one another.

[7] Which being very robust, are disposed circularly round the Artery, (*per* §. 134.) whose Diameter they contract.

[8] The Coats of the Arteries, especially of the larger, are replete with small Blood-vessels coming from the Coronaries, and from the Parts to which the arterial Trunks are connected. These running or spreading themselves through the cellular or second Tunic (§. 132.) of the Artery, appear so numerous when distended with the Injection of *Ruysch*, that one would imagine them to make up the greatest Part if not the whole Substance of the Vessel. 'Tis remarkable that these small Arteries of Arteries are in their Diastole when the Arteries they compose are in their Systole, which Action they forward by their Turgescence; but when the larger Arteries are dilated, these small ones, spent in their Tunics, are compressed, and their contained Blood evacuated, like the coronary Arteries of the Heart (§. 183.) see more at §. 132. N°. 8. Besides these, the Contraction of the Arteries is also assisted or promoted by the Elasticity and Compressure of all the adjacent Parts contiguous to the Artery, and which it removes into its Diastole, whose Force will shake the whole Limb, if you lay the Ham of one Leg over the Knee of the other.

§. 214. Nor is there *any* [1] sensible Part throughout the whole Body, but what is furnish'd with some small Artery; as we are assured from *Wounds* [2], *Microscopes* [3], and *Injections* [4]: Even in the very middle of the Bones do we find the same Membranes, Ves-

sels

ſels and Fluids, as in the other Parts; but all theſe ſmall Arteries, every where obſerved, are little Branches of the *Aorta* [5].

[1] *Galen* and the Ancients diſtinguiſhed many Parts of the Body by the Name of Spermatic, which they ſuppoſed, even till the laſt Century, not to be nouriſhed from the Blood; but theſe Parts have been ſince demonſtrated by the Induſtry of *Ruyſch* to conſiſt almoſt entirely of Veſſels capable of receiving his ceraceous Injection, by which he ſhews that even the compacteſt Bones, Cartilages, Membranes, Ligaments, and Tendons are all furniſhed with the ſame Arteries as the ſofter Parts, only many of them ſeem too ſmall to admit the red Part of the Blood.

[2] One cannot enter the ſmalleſt Needle through any Part of the Cuticle but the Blood will follow it; but this Blood iſſues rather from the ſmall Arteries than the Veins, becauſe the former extravaſate it with the greateſt Force; whereas the Veins, even pretty large ones, diſcharge but little Blood and but ſlowly.

[3] By theſe we are enabled to ſee an infinite Number of ſmall Arteries, with the Blood running through them, in the Tails and Fins of little Fiſh, and in ſuch other Parts as one would otherwiſe take to be mere membranous Expanſions.

[4] By the Artifice of Injections, a moſt admirable Improvement in Anatomy, we diſcover every Part within the Cuticle to be vaſcular. The Preparations of the celebrated *Ruyſch*, who has induſtriouſly excell'd in this Practice, ſhews the otherwiſe pellucid Membranes to be beautifully painted with Ramifications of Arteries; even the hard Tendons and compact Ligaments being cut in ſunder after they have been injected, demonſtrate many

ny ſmall Arteries running through their Subſtance. That indefatigable Anatomiſt has even injected the white and ſolid Cartilages of the Bones, after macerating them eight Days in Water, made a little ſalt to prevent Putrifaction.

[5] I need hardly obſerve that in the Liver and Lungs you may in ſome meaſure make an Exception; but even theſe are plentifully furniſhed with Arteries from the Aorta; in the Liver, *Ruyſch* has demonſtrated a vaſt Number of ſmall Arteries from the Cyſtico-hepatic, Ligamentary, Pericardio-diaphragmatics, *&c.* but in the Lungs his bronchial Artery is ramified throughout.

§. 125. The Blood being propelled into the Aorta, meets with a Reſiſtance from that with which the Arteries are already *fill'd* [1], as alſo from the *Incurvations* [2], *Elaſticity* [3], and *conical Figure* [4] of the Arteries, with the Reſiſtance of the contiguous Parts, *preſſing* [5] on the Arteries by their Weight and elaſtic Nature, and laſtly, from the exceeding *Narrowneſs* [6] of the ſmalleſt Veſſels: So that this Fluid paſſes through the Veſſels only by the *Exceſs* [7] of the Force given it by the Heart above the Sum of all the Reſiſtances; but as theſe Reſiſtances are leſs in the *Lungs* [8], the weaker Contraction of the right Ventricle is therefore able to propell the Blood more eaſily through them, conſidering this Viſcus barely as a Part of the Body, or as it exiſts in the Fœtus in Utero, without any Regard to its Office of Reſpiration.

[1] Were

[1] Were the Arteries quite empty, the Blood would then meet with little Reſiſtance in them, and no great Force of the Heart would be required to fill them; but the Arteries of a Perſon in Health are always full (*per* §. 213.) as well in their Syſtole as Diaſtole: For were only ſome of them empty, the Blood would ruſh into them ſo impetuoſly as to cauſe a Rupture; or were only ſome Arteries leſs full than others, the Blood would even then deſert its Courſe to the Brain, and fly to the leſs reſiſting Veſſels, whence would follow a Deliquium, as is the Caſe in a profuſe Hæmorrhage, or Phlebotomy. The Blood therefore which is thrown out of the Heart drives forward the reſt already in the Arteries; but that the Quantity of Blood and Juices thus moved at each Syſtole of the Aorta is very large, may appear from their being much ſuperior to the whole Maſs of Solids, according to the Computation of Dr. *Keill*; and one may, at a moderate Eſtimate, compute that in a Man weighing 200 Pounds, there are not above 110 of Solids, including the Skin and Fat; ſo that there will then remain 90 Pound of Juices which reſiſt the Blood thrown out of the Heart into the Arteries at each Syſtole. Even the ſolid Hoof of a Horſe is not ſo compact nor dry but if the Farrier ſhaves it too deep it bleeds very profuſely.

[2] Some Geometricians affirm that by Experiment a Liquor paſſes as ſoon, or in the very ſame time, through an inflected Tube, as through one that is ſtreight. The Difference may indeed be granted very imperceptible in Tubes that are ſmooth, rigid and not elaſtic, but every where cylindrical and of an equal Diameter, and with Liquors having but little Coheſion or Viſcidity; but

it

it is otherwiſe betwixt the Blood and the elaſtic or inflected Arteries of the human Body, which being frequently complicated or incurvated at right Angles, make a great Reſiſtance to the Courſe of the Blood.

3 So great is the Strength and Reſiſtance of the Arteries, that the larger Trunks can ſcarcely be diſtended with Water by any Force; and their Reſiſtance would be probably too great for the Heart to overcome, if they were not continuous to the Veins, where the Reſiſtance of the Blood from the Sides of the Veſſel continually diminiſhes.

4 In a Tube whoſe Shape is that of a converging Cone, like the Arteries, it is univerſally allow'd that a greater Force is requir'd to dilate the Sides as the Force is apply'd nearer the Apex or Extremity. But we have here uſually two Objections made: (1.) That the Diameter of all the ſmall Arteries taken together greatly exceed that of the Aorta next the Heart, and that therefore the arterial Syſtem is not to be conſidered as a converging Cone, but rather as a Cone diverging. But we anſwer, that the Arteries have from their Shape, notwithſtanding the Friction and Reſiſtance proper to a converging Cone; for they are dilated more near the Heart than towards their ſmaller Extremities, which is not the Property of a diverging but of a converging Cone; and we find, by Experiment, that the Diameter of the Aorta is proportionably more increaſed near the Heart than at ſome Diſtance, and that the Branches dilate ſtill leſs in Proportion, and the Capillaries leaſt of all. (2.) The ſecond Objection is, that all the Arteries have not a conical Figure; for the carotid paſſing to the Brain through a bony Canal is there contracted, and again dilated or enlarged within the Cranium, and then again contracted.

tracted. But we anſwer, that even the Carotid has a greater Dilatation near the Heart than at the Brain, and if it any where puts off the Figure of a converging Cone, we need not wonder that it ſhould alſo be without its Affections; but then this is true only in the Part of the Artery thus changed from its common Shape and Diſpoſition.

5 Beſides the Preſſure on the Arteties from the adjacent Bones, Muſcles, Fat, *&c.* they are alſo compreſſed by the Atmoſphere, which they remove with the adjacent Parts in every Diaſtole; which conſiderable Preſſure of the Atmoſphere only, is equal to the Weight of a Column of Water thirty two Feet perpendicular. Some indeed deny this Preſſure of the Air, notwithſtanding it is ſo evident; becauſe, ſay they, we do not perceive any ſuch Preſſure on our Bodies, which is owing to the Reſiſtance of the internal Air included in our Bodies ſuſtaining the Weight of the external; but it is certain that when the Preſſure of the external Air is removed from any Part by Cupping-glaſſes, or otherwiſe, the Blood and Juices ruſh more violently into the Veſſels of that Part than of any other, from their leſs Reſiſtance by removing the Preſſure of the Air. 'Tis alſo well known that all Animals ſwell ſurpriſingly in the exhauſted Receiver of an Air-pump from the Juices running more copiouſly into the Veſſels of the external Parts, which by exhauſting the Air have a leſs Preſſure and Reſiſtance againſt the Blood. Nor do we know of any Part beſides the Lungs which contains Air truly elaſtic, and none but ſuch is capable of reſiſting the Weight of the Atmoſphere, and of ſupporting the Parts of our Bodies againſt its Preſſure.

6 A Liquor flows with a much greater Velocity through two or three Tubes of a determinate Capacity than through a great Number of ſmall Tubes whoſe Lights or Diameters added together are equal to the former ; for it appears, from the Principles of Hydraulics, that to fill or diſtend an hundred ſmall Tubes requires a much greater Force than to fill one Tube of the ſame or equal Dimenſions : Nor is it difficult to account for the Phænomenon which ariſes from the greater Friction and Reſiſtance of the Liquor againſt the increaſed Surfaces of the Tubes, or Cylinders, a large Tube having a leſs Surface in Proportion to its Contents than a ſmall one ; ſo that if an hundred Globules were to paſs through a certain Tube, only a few of them which lay next the Tube would ſuffer the Reſiſtance of Friction from its Sides, but if that Tube was ramified into an hundred, all pervaded by the ſame Liquors, then every Individual Globule would ſuffer a vaſt Friction, by coming into contract with each Tube, whence the Friction would be ſurpriſingly augmented. And thus it is with the Arteries of the human Body.

7 The Force of the Heart is more than equal to the Reſiſtances, ariſing from the Blood already in the Arteries, from their conical Figure, various Inflections or Incurvations, Elaſticity, and Smallneſs, or the Multitude of Ramifications, with the Preſſure of the Air and circumjacent Bodies ; for was the Force of the Heart barely equal to theſe Reſiſtances, according to Dr. *Keill*, the Blood would then ſtand ſtill from the Equilibrium ; but we find that it moves forwards in the Veſſels with a Velocity equal to the Exceſs of the Heart's Force above thoſe Reſiſtances.

8 For an equal Quantity of Blood is propell'd through the Lungs, by the weaker right Ventricle

cle of the Heart, in the ſame time that a like Quantity is propell'd throughout the whole Body by the ſtronger left Ventricle (*per* §. 184.); whence it follows, that the Blood meets with leſs Reſiſtance in the Lungs, partly from the Air's ſuſtaining the vaſcular Plexus ſpread on the Veſicles of this Viſcus, and preſſing leſs on them than the cutaneous Veſſels, and partly from the pulmonary Veſſels being fewer in Number and leſs inflected than thoſe of the whole Body beſides.

§. 216. From what has been ſaid we muſt therefore conclude the Power of the Heart to be very conſiderable, as well from computing the Force by which it overcomes or *exceeds* [1] the ſeveral Reſiſtances, as from conſidering barely the vaſt Quantity of Juices *to be moved by it* [2].

[1] It is by this Exceſs of Force that the Heat of animal Bodies is generated; when at the ſame time Water never acquires Heat tho' moved with the greateſt Velocity, even in the magnificent and regal Water-works and Engines at *Verſailes*, erected by *Lewis* XIV. But the Difference betwixt theſe Hydraulic Engines and thoſe of animal Bodies, productive of Heat, is, that in the laſt both the Tubes and Juices are elaſtic, the Particles of the Blood and Juices are very viſcid and adheſive to their Sides and to each other, the Veſſels infinitely ramified and inflected into converging Capillaries; by all which the Frictions and Vibrations both of the Veſſels and Juices are ſo far increaſed above the former, as to produce Heat, always proportionable to the Blood's Velocity and Diameter of the Arteries through which it paſſes; for in a large

large Artery where the Blood moves ſwifteſt there is little Friction, but in the ſmaller Arteries where it moves ſloweſt there is a greater Friction, whence the Equality of the Blood's Heat both in the larger and the ſmaller Veſſels.

[2] So abundant that Dr. *Keill* computes nine Parts out of ten are Juices in the human Body; and by a more moderate Computation there are 90 Pounds of Juices circulating by the Force of the Heart in a Man weighing 200 Pounds.

§. 217. Since therefore the whole Maſs of Blood is drove forwards with ſo great a Force (§. 216.) and again *repell'd* [1] by ſo many and great Reſiſtances (§. 215.) in paſſing through a full, conical, *pliable* [2] and very elaſtic Veſſel; it therefore neceſſarily follows that the Dilatation of this Veſſel or Artery is contemporary with the Contraction of the Heart, and that this Dilatation, which is the natural and unactive State of the *Heart* [3], is the preternatural or *violent* [4] State of the Artery; and that this Dilatation of the Arteries is performed in every Part of a healthy Body at the *ſame Inſtant* [5] of Time, as we are aſſured from their being all full; but then this Diſtention of them is the moſt perceptible where the Arteries are found ſeated upon hard reſiſting Bodies, as the Bones, and where they lie moſt *expoſed* [6] or uncover'd.

[1] If the Blood met with no Reſiſtances in the Arteries, it would paſs freely through them into the Veins without ever diſtending them; but by their Figure, Plenitude, and other Affections the

Blood is forced againſt their converging Sides, which conſiſting of circular and elaſtic Fibres are equally dilated from a ſmaller to a larger Diameter, and that even without any ſhortening of the Arteries, which are kept extended to their full Length by the reſiſting Bones.

[2] Were the Arteries to become rigid, Death would be the Conſequence, becauſe the Heart would not be able to overcome their Reſiſtance; and this it is that occaſions Death from mere old Age as well in human as brute Animals; *viz.* the Arteries become too tough and rigid by their frequent Action, the Tendons become inflexible and indiſpoſed for Motion, and the Cartilages turn bony, *&c. Vid.* §. 468, and 475.

[3] For this hollow Muſcle is naturally flaccid and dilated, like all other Muſcles, when at reſt; but its Contraction follows from other Cauſes not within itſelf, *viz.* the Force or Influx of the nervous Juice from the Cerebellum, and the Impulſe of the arterial Blood impell'd by the Aorta into its coronary Arteries, *per* §. 187, and 190.

[4] As ariſing from the Impulſe of the Blood given by the Force of the Heart; but when that Impulſe ceaſes, the Artery being left to itſelf contracts by the Elaſticity of its Fibres, and then ſtops a while in its greateſt Contractions, *per* §. 132.

[5] Mathematically ſpeaking, they do not abſolutely all dilate at the very ſame and leaſt Inſtant of Time as the Motion is ſucceſſive, but the Difference is not ſenſible in a healthy Perſon; tho' in one that is dying, the Heart and larger Arteries beat when you can perceive no Motion in the ſmaller Arteries of the Limbs. To expreſs the imperceptible Variation of Time, the 3,600th Part of an Hour muſt be divided into an infinite Number of

Parts

Parts, and again divided proportionable to the Diſtances of the Arteries from the Heart; but I will not inſiſt on ſpeculative Subtilties.

[6] Becauſe thoſe reſiſting Bodies return the whole Diaſtole of the Artery upon the Finger of the Phyſician; thus it is in the Arteries of the Temples, Carpus, Angles of the lower Jaw, inner Corners of the Eyes, *&c.* but when the Artery is inveſted with much Fat, its Ictus is loſt in that ſoft Subſtance, and makes little or no Impreſſion on the Finger; whence the Pulſe of a lean Perſon will ſeem four times as ſtrong as that of a fat one, tho' in themſelves they are both of equal Strength, and the Perſons equally in Health.

§. 218. But while the Artery is in this Diaſtole or Dilatation (§. 217.), it exerts a ſtrong *Reaction* [1] by its elaſtic Power (§. 213.) in a contrary Direction, and being aſſiſted at the ſame time by the reſiſting Power of the circum-ambient Parts (§. 215.), the Artery will conſequently contract, and forcibly propell the Blood, as well by its own (§. 213.) as the received Preſſure, without which the Blood would ſtagnate; and from this Power therefore of the Artery its contained Blood runs forwards in a Stream continued, but ſomewhat ſtarting, eſpecially at the Inſtant of the Heart's Contraction: This State of the Artery is call'd its Syſtole, being Contemporary with the Diaſtole of the Heart, and makes the *natural* [2] or unactive State of this Veſſel, whoſe Contraction is aſſiſted by the Meeting or Return of the *Valves* [3] in the Aorta, and the *Emptineſs*

and *Flaccidity* [4] of the coronary Arteries. But during the Contraction of the Heart, the Arteries and Veins contain as much more Blood than during its Diaſtole, as will fill the two Ventricles, which Quantity they protrude into the Arteries at each Contraction, beſides the Blood expreſſed out of the coronary Veſſels of the Heart; but on the contrary, when the Heart is dilated and the Arteries contracted, the Veſſels contain ſo much leſs Blood than before; that Quantity being poured into the Ventricles; whence you may compute the Difference of Capacity in the Arteries when in their Syſtole and Diaſtole.

[1] This Re-action may be compared to and underſtood by that of a tenſe Chord, ſtruck or forced by ſome Weight; but if we conſider the greater Ratio or Proportion that the right Auricle bears to the left, *viz.* as 5 to 3 according to *Santorini*; it will not ſeem improbable that the right Auricle is ſo much larger to ſerve as a Diverticulum to the venal Blood, when it is ſent faſter to the Heart than it can protrude it through the Lungs, as in ſudden Exerciſe, Fear, Cold, *&c.*

[2] A State which the Artery acquires of itſelf and of its own Nature, whereas the Diaſtole ariſes from a Cauſe not in the Artery but in the Blood, *viz.* the impelling Force of the Heart.

[3] When the Aorta contracts itſelf, it preſſes the Blood every way as well towards the Heart as the Extremities; but to prevent any of the Blood from entring the Heart again out of the Aorta, which would confound the Action of the Muſcle, the ſemilunar Valves meet ſo exactly as not to admit

mit one Drop to pass betwixt them; by which means the whole two Ounces of Blood propell'd by the left Ventricle into the Aorta, is drove forwards through its smaller Branches, except only about one Dram that enters the coronary Arteries of the Heart itself.

[4] The Force of the Arteries propells the Blood even in the Veins till it enters the right Auricle again; but then the Ventricle of the Heart itself is not fill'd with the venal Blood by arterial Force but by the Contraction of the Auricle. To this we may add that the Systole of the Arteries is also in some measure promoted by the Repletion of the small Vessels in their Tunics from the Coronaries, during their Systole.

§. 219. These two Motions of the Artery (§. 217 and 218.) make up what Physicians call the *Pulse* [1], in which they usually consider its *Strength* [2], *Largeness* [3], *Fulness* [4] or Tensity, *Quickness* [5], and *Equality* [6], with their Opposites; tho' these are hardly ever observed in any two healthy Persons *alike* [7].

[1] This, strictly speaking, is only the Diastole of the Artery, since the Finger can only perceive it in that State, being insensible when it contracts into a less Compass from under the Finger.

[2] The determinate and strong Force with which it repells the Finger in each Diastole.

[3] The Difference betwixt the largest Diameter of the Artery in its Diastole, and the smallest Diameter in its Systole; whence, in a healthy Person, a large Pulse denotes a large Quantity of Blood thrown by the Heart into the Aorta.

[4] A full Pulſe is one that feels large in its Diaſtole, and does not contract much in its Syſtole; but I make little or no Difference betwixt this and a large Pulſe.

[5] The Frequency of the Pulſe is meaſured by the Number of Dilatations which the Artery makes in a given Time, either in Health or Sickneſs; but as this is comparative, therefore the chief Phyſicians to Princes ought to learn the Frequency of their Sovereign's healthy Pulſe, that they may judge of its Variation when diſeaſed. In general, healthy Pulſes vary according to the Age, Sex, Climate, *&c.* from 60 to 100 in a Minute; but they are ſeldom below 70 or above 90, and are moſtly about 75 or 80. In Fevers they often run to above 120.

[6] Equality of Strength, Magnitude, Plenitude, and Number, either ſeparately or conjunctly; which Equality is an exceeding good Sign in all Indiſpoſitions, denoting the Return of Health, in which it is a conſtant Companion.

[7] As *Bellini* obſerves. (See alſo §. 217, N° 6.) Nor are the Pulſes of one and the ſame healthy Perſon nearly alike at various times, and under different Circumſtances; for there is a wide Difference in their Number and Affections, according as the Perſon is either in a Paſſion, ſleeping, meditating, exerciſing, faſting, after Dinner, *&c.* for as the Reſiſtance of the Arteries varies, ſo does alſo their Irritation, and the Force of the Heart, whence ariſes the Difference of their Vibrations or Pulſes.

§. 220. The Blood then, being drove out of the Heart in an oblique Direction againſt the Sides of the Aorta, ſtrikes and preſſes on them

them in a very *acute* [1] Angle, whereby almoſt the whole Quantity thrown into it by the Ventricle will be forced againſt its *Curvature* [2] or Arch, where meeting with a Reſiſtance from the Figure and Elaſticity of the Veſſel with the Weight of the preceding Blood, it is thereby *repell'd* [3] in all Directions: Hence therefore the Particles of the Blood will every Moment receive a different *Motion* [4], *Colliſion* [5], and *Rotation* [6]; as alſo a conſtant *Attrition* [7], *Attenuation* [8], and *Compactneſs* [9], with an Abraſion or *Levigation* [10] of their Angles, and an Uniformity or *Similitude* [11] it each Particle. From all which will ariſe that *Fluidity* [12], *Heat* [13], and *Colour* [14] obſervable in the whole Maſs, with that Diviſion of its Parts fitting them *to paſs through* [15] all the ſmall Veſſels; hence alſo the Preſſure of them into the *lateral Orifices* [16] and Branches to which the Particles of the Blood are convey'd, and the Prevention of them from forming Obſtructions in the *Capillaries* [17], all which are ſtill farther promoted by the numerous Anaſtomoſes ſo frequently obſerved among the ſmall Arteries, by which the Parts of the Blood meet every Moment with oppoſite Colliſions, Diviſions, Commixtures, and Separations in their Courſe. Nor do we ſtand in need of any other *Cauſe* [18] beſides this Motion, to account for all the forementioned Effects or Appearances.

[1] The Blood propell'd by the Heart into the Aorta dilates the Sides of it more than of the ſmaller

Artery; and as the Contraction of the Artery, is, ſtrictly ſpeaking, ſucceſſive from the Heart (*per* §. 217, N° 5.) the Sides of the Aorta at the Heart therefore contract before the reſt, though inſenſibly. But from the converging or conical Figure of the Arteries, the Parts of the Blood do not enter them in Lines parallel to their Sides, but impinge on them in an oblique Direction or in an acute Angle. But when elaſtic Bodies, like the Blood-globules, ſtrike againſt elaſtic Chords, like the component Fibres or Sides of the Arteries, they will be repell'd by the common Law of Reflection, in an Angle equal and contrary to that of their Incidence; whence the whole globular Maſs impinging obliquely againſt the Sides of the Arteries, will be again reflected with an equal Obliquity againſt their oppoſite Sides; and this Reflection will be continued or repeated from one Side to the other till the Artery terminates. Thus the component Globules of the Blood will receive a perpetual Attrition both againſt the Sides of the Arteries and againſt each other; and by the infinite Ramification of the latter, no Globule will find a Paſſage into the Veins without having firſt touch'd in every Point againſt ſome Artery; but in the very laſt Extremities of the Arteries, which admit only ſingle Globules to paſs, by changing their ſpherical for an oval or oblong Figure, there will be almoſt a compleat Contract both betwixt the Veſſels and Globules, ſo that no Particle of the Blood will paſs without a previous Attrition.

2 The Aorta is incurvated ſoon after its Egreſs from the Heart, and forms a conſiderable Arch, againſt which the Blood is impell'd from the Heart, and thereby changes its Direction, which was firſt given it towards the Axis of the Artery; but even in the ſmaller Arteries we meet with many

ſuch

ſuch Incurvations, by whoſe Re-action the Blood will be repelled in various Directions, and the Globules ſtriking againſt each other will acquire a rotatory Motion, and an Attrition of their Sides, *&c.*

3 The Contraction of the Aorta propells the Blood every way, as well towards the Heart, from whence it came, as towards the Extremities; but the three ſemilunar Valves of the Aorta cloſe ſo as to prevent any of it from re-entring the left Ventricle, and only two or three Drams enter into the coronary Arteries, which open within the Reach of thoſe Valves, all the Remainder of the Blood expell'd by the Heart being at the ſame time determined and urged by the Syſtole of the Aorta towards the Extremities of the ſmaller Arteries. Now if the Blood flow'd thus through an empty Tube, without Reſiſtances, it would every where run over equal Spaces in equal Times, and continue in the Direction which it firſt acquired; but the Caſe being otherwiſe in the Arteries, the Blood does not move through them uniformly, but with a Direction and Velocity that varies: For the Particles of the Blood, and the Sides of the Arteries being elaſtic, are ſubject to that Law of Motion in elaſtic Bodies, by which, after Colliſion, they recede from each other in oppoſite Directions, and with the ſame Force that they met together. Theſe Colliſions will be therefore frequent betwixt the Blood and the Arteries, and more frequent in the ſmaller than in the larger Arteries; becauſe ſmall Cones have proportionably a greater Surface than large ones: Alſo by this Colliſion and different Preſſure of the Sides of the compound Globules againſt the Arteries and againſt each other, they will be compacted, render'd more ſolid, and acquire

quire a vortical Motion; which laſt will both give them a Sphericity and a Poliſh.

4 The Globules of the Blood moving naturally in the Direction of the Axis of their Artery, will be turned out of that Courſe by ſtriking againſt its Sides and various Incurvations; ſo that the impinging Blood will be forced by the Sides of the Arteries towards their Axis, againſt the ſucceeding Blood, which will again drive the preceding upon the arterial Sides as before, and in various Directions; by which means no two Globules will continue one Moment together, or in Contact, and being every way compreſſed, they cannot divide themſelves into leſſer Globules.

5 By which the Niſus or Tendence of all Bodies to move on in a right Line with the ſame Velocity, is in the Blood-globules continually changed, as well by their various Angles of Incidence and Reflection, as by their different Oſcillations and Repercuſſions among each other.

6 Every ſpherical Body that even moves upon a ſmooth Plain, will revolve about its own Axis, and deſcribe a Cycloide; whence the Contacts and Attrition of the ſeveral Particles in the Blood will be continually changing, and leave no Points or Angles in them unlevigated.

7 The Blood-globules are compreſſible, and have an expanding Force, by which they act on each other, and on the Sides of the Arteries, eſpecially in the very minute and elaſtic Capillaries through which they are forced with ſo great a Velocity; and hence it is the Heat of the Blood ariſes. (*Vid.* §. 229.)

8 By the Diviſion of the larger Globules into leſs as they ſtrike againſt the Angles of the ramifying Arteries.

9 Their Denſity or Compactneſs will ariſe from the Union of ſeveral ſmall Globules into a larger one,

one, which will retain the Weight of all the ſix united Spherules under a leſs Surface; and it is a Diminution of the Surface without removing any of the Weight that increaſes the Denſity or ſpecific Gravity of Bodies. To this add the Abraſion of angular Parts, and the cloſer Approximation of the reſt by a conſtant and equilateral Preſſure; by all which means the Particles of the Chyle and Milk, in themſelves lighter than Water, are converted into Blood, which is a twelfth Part heavier than Water, even tho' it be extravaſated, for I ſuppoſe it was more compact in the Veſſels as it is there compreſſed, but expands in the Air, as we may conclude from the Diſſillition of the Globules, or the Cruor's turning into Serum by ſtanding.

[10] A Sphere moving among other Bodies meets with an equal Reſiſtance in all the Points of its Surface, in which if there are any Angles or Inequalities more remote than other Parts from the Centre, the Reſiſtance or Attrition will be the ſtrongeſt upon them, ſo as to abrade and grind them off; whence the Sphere will be compleated and move freely in every Point. By theſe means every nutritious Particle of our Chyle, aſſumes a globular Form, except the excrementitious, earthy and ſaline Parts, eſpecially thoſe of common Salt, which *Lewenhoec* has obſerved floating in the Serum of the Blood; for ſo retentive are the Particles of that Salt of their natural Cuboide Figure, that after they have paſſed the Circulation, and been putrified in the Urine for three whole Years, they receive not the leaſt Change. *Vid.* my Chemiſtry, Book II. Proceſs 101.

[11] This homogeneous or uniform Texture of the ſeveral Parts of the Blood, being that of Spherules, varying only in Size, ariſes from their Attrition among

among each other, whereby the angular Parts are abraded; for while the alimental Particles in the Blood continue rough and unequal they are rather offenſive than nutritious, and are not properly Parts of the Blood. Hence you may reſolve the great Queſtion how all ſorts of People feeding on different Aliments make the ſame Blood from each; for this Change ſeems to ariſe chiefly from the Lungs (§. 200, N° 11.) and Arteries, compacting and levigating the ſmaller Spherules of our alimental Juices (§. 127.) into the larger Globules of Blood and Lymph, agreeing in Weight, Solidity, and Colour; including alſo the Action of our indigenous and chylificative Juices (§. 126, N° 6.)

12 There is ſome Difficulty in accounting for the Blood's Fluidity in the Veſſels, when it even congeals in them, and becomes a ſolid Maſs barely for want of Motion; but neither its Heat nor progreſſive Motion in the Veins are ſufficient for this (conſidering the Viſcidity and coheſive Nature of its Parts) without the Interpoſition of a certain Portion of the univerſal Menſtruum Water, and an inteſtine or rotatory Motion in each Particle preventing their Combination with each other, to which add the Efficacy of the Lungs (§. 200.) The Ancients indeed imputed this Fluidity of the Blood to a Ferment, when they needed nothing more to account for it than the conical Figure and Action of the Arteries, with a ſufficient degree of Motion in the Blood communicated from the Heart; for otherwiſe, the Blood not only congeals after Extravaſation, but even in the Veſſels polypous Concretions are ſometimes formed in a Syncope in leſs than one Minute's time.

13 The Heat of the Blood ariſes in an eminent degree from the elaſtic Vibrations or Contractions

of

of the Arteries, ſince a Man whoſe Blood is almoſt frozen will recover his Heat barely by Exerciſe or muſcular Motion. The Heat of the Blood then in the human Body is proportionable to its Velocity and Number of the red or largeſt Series of Globules it contains; the Intenſity and Variation of which Heat may be moſt commodiouſly eſtimated by the mercurial Thermometer of *Farenheit* of *Amſterdam*. If the Bulb of this Inſtrument be inſerted into a Patient's Mouth, after you have marked the Degree of the Atmoſphere, and the Patient ſhuts his Mouth, breathing only through his Noſe, the Aſcent of it will then indicate how much he is hotter than the Air; which freezes at 32 *gr.* is cold at 40, temperate at 50, warm at 65, and ſultry (at which Butter oils) at above 80, tho' 'tis tolerable for ſome Hours in a Bagnio at above 90, equal to the uſual Heat of the Sun at Noon in the Dog-days, and from 96 to 100 is the healthy Heat of human Bodies, which in Fevers aſcends to 110, and even Water ſcalds a ſoft Hand when heated to 112 or 114; the White of Eggs, Serum and Lymph harden at about 155; Alcohol boils at 175, and Brandy (which is half Water) at 190, Spring-water at 212.—Hence as there is ſo little Difference betwixt ſcalding Water and the Heat of the Blood in ardent Fevers, no wonder that they ſo ſoon evaporate the aqueous Parts, and inſpiſſate the reſt of the Blood, and then induce a putrid Thinneſs; or that they are often not tolerable above three Days, and by that time the ſoft Brain is in a manner parboiled or ſcalded; and the Texture of the Blood is often ſo diſſolved that a Dropſy attends the Patient after his Recovery from the Fever, cauſed by a Diſſolution of the larger red Globules into leſſer ſerous ones. If the Motion and Heat of the Blood decreaſe, it becomes ſerous

or

or watery, and a Cachexy follows. But ſome will ſay, that the Heat of the Blood is not always as the Quickneſs of the Pulſe; this I allow, for the Pulſe may be very quick and the Blood at the ſame time move ſlow, as in a Perſon that is dying.

14. We are aſſured that no other Cauſes are required to make the Blood red than the Action of the Lungs and of the Arteries, by which the largeſt Globules not only aſſume that Colour but are alſo formed equally large, denſe, ſmooth, and ſpherical; for when the Force of the Arteries is diminiſhed, the Blood ſoon loſes of its red Colour. If a Man in perfect Health is any way weakened, and his Circulation, or the Heat and Attrition of his Blood thereby diminiſhed, he will in a little time look pale, and his Blood will become ſerous or diſcoloured. Girls, at the firſt Appearance of their Menſes, often loſe their Colour, look pale, and have a Weakneſs in their Limbs and Coldneſs all over their Body; their whole Skin alſo turns of a pale, greeniſh, or yellowiſh Hue: And their Blood, upon Examination, has very little Redneſs in it, but appears watery, and like the Waſhings of Fleſh, which is alſo the State of the Blood after Intermittents, and many chronical Diſorders. But ſuch a Girl, by various Exerciſes with Chalybeats and Corroborants, which increaſe the Velocity, Attrition, and Heat of the Blood, will recover her former Health and Beauty. We therefore need not call in any Effervescence of an acid Chyle with the Blood to account for its Redneſs, nor any Mixture made in Vacuo, nor the Action of any alcaline Salt, as that of the Sal Tartari boil'd with Milk.

15. To render the Parts of the Blood pervious to all the Veſſels, it required to be ſtock'd with Globules

bules of various Sizes, correſponding to the Orifices of the ſeveral Series of Veſſels; but this is effected by the Diviſion of the larger Globules into thoſe of leſſer Orders by the Action of the Lungs (§. 200.) or pulmonary Arteries; and that the larger Globules will thus diſſolve into leſs, is proved to the Eye by the Microſcope, when the Cruor has enter'd a Veſſel too ſmall for its Paſſage.

16 When ſmall Branches go off from a converging Veſſel or Artery, towards its Apex, having Orifices too ſmall to admit the red Part of the Blood, I ſay that in theſe lateral Orifices will enter all thoſe fluid Particles which are either of an equal or leſs Dimenſions; while the more groſs Particles, by whoſe Weight and Preſſure the more ſubtile were forced into the lateral Orifices, go on ſtill towards the Apex of the Cone or Veſſel: Hence, the ſmaller and fewer the lateral Branches or Orifices, the more of the Juices will continue moving forward in the arterial Trunk.

17 The Blood would be in imminent Danger of ſtagnating and concerting in the Extremities of the ſmall Arteries, (where its Motion is ſloweſt, its Reſiſtance greateſt, (§. 215.) its Heat the leaſt, and its diluent or thinner Juices in the ſmalleſt Quantity) if it were not highly attenuated by the arterial Plexus's ſpread through the Lungs (§. 198.) and Muſcles; in which, by their frequent *Anaſtomoſes* with each other, like the Marſhes of a Net or a Spider's Web, every individual Particle of the Blood is propell'd in various and contrary Directions. If any Obſtructions are formed, by theſe Inoſculations, the obſtructed Capillaries are alſo prevented from being either totally block'd up or burſt, by the Impulſe of the ſucceeding Blood, which will take its Courſe freely through the next communicating Branch, till the obſtructing Mat-

ter

ter be either attenuated and diſſolved, or elſe protruded through or removed by the frequent Shocks of the Artery. When one has got a Cold, with a Defluxion on the Fauces and Parts adjacent, there are then an infinite Number of ſmall Arteries obſtructed which deny a free Paſſage to the Blood; but all this is quickly diſperſed and removed by a Day's faſting, and plentiful drinking of warm diluent Liquors; for thus the obſtructive Matter will be attenuated or removed, and Arteriolæ become pervious as before. And *Lewenhoec* has often ſeen the Particles obſtructing a capillary Artery diſſolve either by an Increaſe of Warmth, the repeated Shock of the Arteriola, or by its returning towards the wider Part of the Artery.

[18] That is the Cauſe of any thing by removing which the Effect ceaſes; but we are aſſured, by Experience, that the Fluidity, Heat, and red Colour of the Blood are always more intenſe when the Arteries and Lungs are ſtrong, and act on the Blood with ſufficient Force; and that they are more faint or remiſs when the Strength of the Arteries and the Blood's Attrition by them is diminiſhed. 'Tis both needleſs and uſeleſs to enter into a Detail of the various Cauſes aſſigned by different Authors for thoſe Appearances of the Blood, ſince they all appear to be fictitious except that here given. Thus a Man lately drowned is deprived of the Heat, Fluidity, and other Affections of the circulating Blood, notwithſtanding all the ſuppoſed Ferments, Salts, Sulphurs, Oils, *&c.* are ſtill within the Maſs, and nothing is wanting but the Motion formerly given it by the Heart and Arteries, which muſt be the Cauſe enquired after.

§. 221. For if the Blood retains all its Parts and Affections, except the Motion given to it by

by the Heart and Arteries, it quickly *congeals* [1], and becomes more a ſolid than a fluid Maſs; but whilſt actuated by the Cauſes (at §. 220.) it continues to be a Liquor adapted to all the Offices of Life.

[1] The Blood, conſiſting of Globules of various Sizes, which only retain their Sphericity while moving faſt enough in the Veſſels, is no ſooner extravaſated, but by preſſing on each other, and by the Force of Attraction they will become little flat Cakes, whereby their Surface being increaſed, and conſequently their Coheſion, they will form a continuous or ſolid Maſs; but this Attraction and Coheſion will be greateſt in the ſmalleſt of the compreſſed Globules, as they will have proportionally the largeſt Surface and Contact; theſe will therefore cohere to each other ſo ſtrongly, by the Help of an intermediate Gluten, as to form elaſtic Chains or Threads. From hence you may underſtand the Formation of polypous Concretions, whether made in the Veſſels, or of extravaſated Blood by Art. The Blood is therefore a Liquor compoſed of Parts naturally apt to cohere and become ſolid, if not prevented by a due Degree of Motion; which is a very neceſſary Affection of it ſo far as it is a nutritious Fluid.

§. 222. But as the Arteries gradually increaſe both in Number and *Capacity* [1], being in ſome Places narrower and in others broader, they will, in every Part, continually *depoſite* [2] or loſe ſome of their Contents, which never return again; but as the Reſiſtances are alſo greater, or even greateſt in the ſmalleſt

Arteries, and much of the Blood's Impulſe is there impreſs'd and loſt upon the *ambient Parts* [3]; therefore the Motion of the circulating Juices will be, *cæteris paribus, ſwifteſt* [4] near the Heart, and ſloweſt in the moſt diſtant Parts or Extremities.

[1] We before obſerved (§. 215.) that the Aggregate or Sum of the Diameters of the ſmall Arteries greatly exceeds that of the Aorta; which we have the leſs Reaſon to doubt of, as we find the Lights or Sections of the firſt Diviſion of the Aorta (into the Subclavians, Carotids, and deſcending Trunks) to exceed the Section of the Aorta itſelf at the Heart, nearly as 3 to 4, or 5 to 6; which Difference will be ſtill immenſely greater as the Arteries are farther ramified; ſo that the Blood moves on continually in the Arteries from a ſmall Capacity to a larger, and will therefore loſe proportionably of its Velocity, as it goes farther from the Heart, till it is almoſt quite loſt at their Extremities opening into the Veins: But *Ruyſch* and *Lewenhoec* demonſtrate that the whole Skin under the Cuticle is ſo full of exhaling Veſſels, that one cannot enter the ſmalleſt Needle without wounding ſome of the Arteriolæ; ſo that almoſt the whole Surface of the Body may be taken as the Area or Section of the exhaling and cutanious Arteriolæ only in Compariſon with a Section of the Aorta; but how prodigiouſly will that be augmented by adding the Sections of all the Arteriolæ of the Muſcles, Viſcera, Bones, *&c.*

[2] Such as all the ſecerned Juices, Lymph, nervous Juice, the Matter of Urine and Perſpiration, (which laſt amounts to five Pounds a Day in *Italy*, according to *Sanctorius*) the Saliva, Tears, *&c.*

&c. all which are more fluid than the Blood itſelf from whence they are ſeparated, and are either diſcharged out of the Body, or at leaſt do not return into the Arteries again: Whence it follows, that the Blood having parted with all thoſe more fluid Juices in its Paſſage to the Extremities of the Arteries, it will be there leſs fluxile, and will move ſlower.

3 A Body moving in a perfect Vacuum, would go on with the ſame Velocity for ever, and in a right Line; becauſe it would not then meet with any other Bodies to change its Direction, nor reſiſt its Motion: But if this Body ſtrikes upon others in its Courſe, it will communicate Part of its Motion to each of them till it has loſt all its own; whence a Stone that has been flung into the Air goes on in a right Line till it has given ſo much of its Motion to the reſiſting Medium, that the Force of Gravity becomes more than equal to its remaining Impulſe, whereupon it falls to the Earth. In the ſame manner the Blood communicates its Impulſe to the Arteries, and theſe again loſe Part of their Motion in removing the ambient and reſiſting Parts, ſuch as the Fat, Muſcles, Skin, Atmoſphere, *&c.* (§. 215. N° 5, 7.) which being ſoft Bodies do not return the Force like rigid and elaſtic ones; for if two Balls of ſoft Clay be ſuſpended by Strings, and impell'd againſt each other in contrary Directions, all their Motion is deſtroy'd, and ceaſes at the Points of Contact; but if they are firſt hardened and baked, ſo as to become rigid and elaſtic, they will then recede from each other after Contact with a Force equal to that with which they met. In this manner a great Part of the Blood's Motion is loſt upon the circumjacent Parts, and eſpecially upon the Fat in People of a corpulent Habit; in which laſt Part

therefore the Blood ſooner ſtagnates and obſtructs the ſmall Arteries than in others.

4 The Difference of the Blood's Velocity in the Aorta and capillary Arteries, is computed by Dr. *Keill* to be at 44,507, to 1. But this Velocity and Motion is both the ſwifteſt and the leaſt impaired in the Arteries of the Heart itſelf; for in theſe the whole Quantity received, in each Diaſtole of the Heart, is forcibly propell'd and diſcharged by the next Syſtole of this Muſcle; ſo that it circulates through the coronary Arteries in the 3600th Part of an Hour (*per* §. 184.). Next to the Veſſels of the Heart, the Blood moves ſwifteſt through thoſe of the Lungs, in which it is accelerated by their Action or Reſpiration, (*per* §. 300 and 308.) and next to theſe it moves quickeſt thro' the Intercoſtals and Phrenics, in which its Courſe or Circulation ſeems to be compleated at every Reſpiration. Nor does the Blood move with the ſame Velocity through the other Parts, but in ſome ſlower than in others; ſloweſt in the Arteriolæ of Adeps and Medulla, in which the Motion is ſcarce ſenſible: But the Blood does not always move in Proportion to its Diſtance from the Heart, for different Circumſtances may make it move an hundred times quicker in ſome than in others; and ſtrictly ſpeaking, its Velocity varies in every Veſſel, in Proportion to its Section and Angle at the Trunk, its Complications, and other particular Affections unobſerved. Thus the carotid Arteries before they reach the Cranium have their Coats denſe and compact; but upon entring the Cranium, they depoſite their thick muſcular Tunic, and become thin as Veins, and larger than before; by which Mechaniſm the Blood flows into them in a greater Quantity, as they have leſs Reſiſtance, and moves ſlower through them as they have a leſs contractile

Force.

Force. Much the ſame Mechaniſm is alſo obſervable in the arterial Branch that conveys Blood to the whole ſpinal Medulla down to the Coccyx, which ariſing from the Conjunction of the two vertebral Arteries at the *Medulla Oblongata*, the Blood takes a retrogade and ſlow Courſe thro' it. *Vid.* §. 231 and 232.

Of the Nature, Compoſition, and Qualities of the Blood.

§. 223. BUT in the ſeveral Conſtituent Parts of the Blood itſelf, is alſo concealed a great deal of the Cauſe both of its *different* [1] Courſe and Velocity in the Veſſels; for that it is compounded of various and diſtinct Particles, we are aſſured from the Matter of its Compoſition; from its ſpontaneous Separation, when at reſt and out of the Veſſels, into a *vapoury* [2], ſerous, and fibrous Subſtance; and laſtly, from the Principles it affords by a chemical *Analyſis* [3].

[1] The Blood is a warm, red, and ſeemingly uniform Liquor, circulating through the Heart and Veſſels of living Animals. If its Parts were perfectly hard and ſimilar, meeting with no Reſiſtances they would go on in ſtrait Lines. And Mechanics teach us, without any Falacy, that, by the Experiments of *Hugens*, if an hundred Ivory Balls are placed upon a ſmooth Table, by giving

an Impulſe to the firſt, the reſt will ſtand ſtill, and impart all their Motion to the laſt, which will depart with the ſame Force and Velocity that the firſt was impell'd with againſt the reſt, and would continue moving in the ſame Direction, and with the ſame Force, if it were not for the Reſiſtance of ambient Bodies. If a Bullet and a Feather are dropt at the ſame Inſtant from a certain Height in the open Air, the Bullet will be down firſt, and leave the Feather floating behind; but if a Feather and a Guinea are dropt at the ſame Inſtant from an equal Height in an exhauſted Receiver, they then both arrive at the Bottom in the ſame Inſtant of Time, all Reſiſtance being there removed. It therefore follows, that a moving Body loſes of its Force by the Impulſe which its Surface gives to the ambient and reſiſting Corpuſcles, and that therefore the Body will be reſiſted in Proportion to the Largeneſs of its Surface; but when ſeveral different Bodies are projected forwards with the ſame Velocity, their Impulſe on others will be alſo, in Proportion to their Denſity or Quantity of Matter under a given Surface. Hence we learn, that in the Particles of the Blood moving all by the ſame Force of the Heart, thoſe will paſs on the ſwifteſt and the neareſt to a right Line which have the leaſt Surface and the greateſt Weight; or to ſpeak mathematically, the Velocity of each Globule will be in a Ratio directly as the Denſity, and inverſly as the Surface. So that if the Globule A be double the Weight of B, it will go over double the Space by the ſame Impulſe in the firſt Inſtant, and in the ſecond Inſtant it will have out-gone B twice as far as it did in the firſt Inſtant of Time; whence their Diſtance from each other will perpetually increaſe, as the times — Another Difference in the Motion, ariſing from their greater Denſity

and

and Sphericity, is that they will move longer, and be more retentive of their firſt Direction in a right Line. If ſeveral leſſer Globules unite into one larger, without loſing any of their Matter, they will become more denſe, or acquire a leſs Surface; but if one large Globule diſſolves into ſeveral leſs they will acquire a greater Surface, if no Change be made in the Texture of their Pores and Particles.

[2] Being that ill-ſmelling Vapour which exhales from Blood juſt extravaſated, of which we ſpoke at §. 167. But the fibrous Parts are no more than Chains of Globules attracting and adhering to each other *(per* §. 221.)

[3] Let ſome Blood of a healthy Perſon run into a clean Glaſs Body, to which adapt a Head, and place them in Balneo with a Heat not exceeding that of a healthy Body, *viz.* 100 gr. you will then have Vapours aſcend and condenſe into an inſipid Water, having little or no Smell, and in nothing differing from common Water, only in having ſome of the fœtid Odour obſerved in the killing or opening of all Animals; nor can we diſcover any acid or alcaline Salt therein by any Experiment. In the next place let the Cake of Cruor, and the remaining Serum in the Body, be urged with a ſtronger Heat of 214 gr. equal to that of boiling Water, and thus you may from a Pound of Blood draw off near ten Ounces of Water, till the remaining Maſs is almoſt dry, which will not then putrify by ſtanding. From this Experiment we learn, that there is not naturally any volatile Salt in the Blood, ſince none aſcends from it by ſo ſtrong a Heat as that of boiling Water. But if you now urge the remaining Maſs with a greater Heat of 300 gr. you will firſt obtain a volatile Salt, with a yellow Oil, then a fœtid or empyreu-

matic Oil, and laſtly a very heavy and thick Oil, leaving a black Maſs, like a Coal, remaining in the Bottom of the Veſſel. But you muſt know that theſe are not the natural but factitious Principles of the Blood, produced or made by the Intenſity of Fire. It is therefore an Error to ſuppoſe that the ſaline Parts of the Blood are naturally acrid and volatile, ſince the Water firſt diſtill'd from it will keep many Years without yielding any urinous or acrid Smell and Taſte.

§. 224. There are therefore in the Blood (1.) ſome Parts already in Motion, and which have a great Diſpoſition to move by the leaſt Impulſe, from their *Solidity* [1], Smoothneſs and *Sphericity* [2], there are alſo (2.) others *ſluggiſh* [3], or unapt to move by a ſmall Impulſe, as being *porous* [4], *angular* [5], rough or *viſcid* [6]: Hence we know, by the Laws of Mechanics, Hydroſtatics and Hydraulics, that theſe Particles of the Blood, though propell'd by the ſame common Force of the Heart, will not all move on with the ſame Velocity, Direction, and Continuance: For the Courſe of the firſt will be ſwifter, longer, and more nearly in a *right Line* [7] from the Heart; while the latter move through the Veſſels more ſlowly, obliquely, and backwards or towards the Sides.

[1] Having the greateſt Coheſion of Parts, with the feweſt Pores or the ſmalleſt Surface; by which they will be more retentive of their Motion, and meet with leſs Reſiſtance, *i. e.* they will be more fluid: Whereas the more light and porous Parts will

will be leſs ſuſceptible and retentive of Motion; *i. e.* they will be more viſcid or leſs Fluid, notwithſtanding their Particles being ſmaller than the former.

[2] Great are the Advantages of this Figure for Fluidity and Motion in Bodies; for it contains the moſt Matter under the leaſt Surface, has every where an equal Reſiſtance, and comes into Contact with other Bodies only in ſingle Points: No wonder therefore that Spheres ſhould aſſume the moſt Motion from the ſame or a common Impulſe, or retain their Motion longer, and their Direction more ſtrongly than Bodies of other Shapes.

[3] Such as are leſs eaſily put into Motion, and the ſooner loſe it; from their Roughneſs, Lightneſs, and their Attraction or Tendence towards other Particles, *&c.*

[4] If two Atoms are conjoined into a Body, with an intermediate Space betwixt them, that Space will be a Pore, and the two Atoms will ſeparate with the utmoſt Eaſe by a Force acting upon them in that Point; and from this Pore it will have a leſs Power on other Bodies, ſince Space has no Action: But if that Body be again diſſolved into two Atoms, each of them will become more ſolid and retentive of Motion, as having no Pore or empty Space; for Matter only is ſuſceptible and retentive of Motion, and therefore in Bodies of the ſame Bulk, thoſe are leaſt porous which have the greateſt Weight, *e. g.* Oil and Fat weigh leſs than Water, and therefore they are more porous.

[5] If a little Drop of the Blood's Serum be taken up in a capillary Glaſs Tube, in a warm Place, and then veiw'd againſt the Light with a Microſcope, it exhibits, beſides Globules, a great many angular or ſharp-pointed Particles, and Spiculæ of a ſaline Nature, which ſeem to be rather Stimuli

to

to the Veſſels than neceſſary or conſtituent Parts of the Blood.

6 Such as ſtrongly attract and cohere to themſelves and to other Corpuſcles, and which therefore cannot be of a round Figure, becauſe they touch and cohere by large Surfaces and not in ſingle Points, and Coheſion we know is as the Surface in Contact.

7 Every Body in Motion endeavours to go on in a right Line, if its Direction is not alter'd by ſome other Force or Reſiſtance; and this *niſus in directum* will be greater as the moving Body is denſer: So that in an Aſſembly of Particles of various ſpecific Gravities moving by one common Impulſe, the heavieſt will keep on their Courſe the neareſt to a right Line, while the leſs heavy recede laterally or obliquely from their firſt Direction. Thus for Example, if you diſcharge a Spherule of Gold, another of Cork, and another of a Piece of Bladder fill'd with Air, and placed in that Order in a Wind-gun; the Spherule of Gold will then go forwards in a right Line, and drive away the other two laterally in Lines of Obliquity proportionable to the Gravity of each. And the ſame it is with the component Globules and Particles of the Blood projected by the Force of the Heart along the Arteries, in which the more denſe and ſpherical Particles will tend moſt in a right Line, or towards the Axis of the Veſſel; while the more viſcid, rough, and porous Particles will be forced towards the Sides and drove into the lateral Orifices. In the ſame manner we obſerve in Rivulets and Currents of Water, that the lighter Soil is forced to the Sides and ſticks to the Shore, while the more heavy is drove with a greater Velocity along the middle of the Current. Hence we learn, that in the Courſe of the Blood

thro'

thro' the Arteries, it does not continue equably mix'd as it was in the Heart, but that various Sorts of its more light and diſſimilar Particles are thrown towards the Sides, and into the ſmall lateral Orifices of thoſe Veſſels according to the Blood's different Velocity in each; while the more compact and ſimilar Particles, the red Globules, continue on their Courſe to the Veins along the Axis of the Artery; and this it is that makes the firſt Preparation of the Blood in order to the various Secretions. To confirm what has been ſaid, if you drive a Mixture of ſmall Shot and round Bits of Wood along a ramified Tube, the wooden Spherules will run into the lateral Branches while the leaden Shot continue on in the Trunk.

§. 225. If it be aſked why the venal Blood in a dead Body is found to retain its Fluidity a long *while* [1] without congealing; when at the ſame time that in the Heart and Arteries is quickly concreted; we anſwer that it is probably owing to the more fluid Parts being continually preſſed and diſcharged into the Veins, while the Arteries in the mean while continually loſe all their more fluid Juices, and receive no freſh Supplies.

[1] In opening dead Subjects the Blood is uſually obſerved uniformly mix'd and fluid in the Veins, even on the third Day; but in the Arteries we find little or no Blood but what is concreted and like a Polypus. The Reaſon of which is, that the Cold contracts all the Fibres and ſmall Veſſels, and the Arteries being much ſtronger than the leſs reſiſting Veins, do continually protrude the moſt fluid Parts of their contained Juices into the laſt mention'd

tion'd Veſſels, while the thicker Parts of the Blood remaining in them concretes; thus the moſt fluid Parts of the Blood will reſide in the Veins and the groſſer in the Arteries, ſo there continues to be a ſort of Motion and Separation in the Blood even a long Time after Death.

§. 226. But though the Blood in a living Body ſeems to be equally red in every Part of it, yet if it be view'd through a *Microſcope* [1] it conſiſts of red Globules ſwimming in a thinner and almoſt pellucid Serum, ſo that every red Globule is made up of ſix ſmaller, which when ſeparated from each other are pellucid and yellowiſh, putting on the Nature of Serum, which appears of various Colours. From whence ariſes the *Subſtance* [2], *Figure* [3], Size, and different Colour of theſe Particles, is apparent from what we have before delivered; but it is not ſo eaſy to know how far this *Diviſion* [4], of the larger into leſſer Globules, is extended; we are however acquainted with the Uſes or Effects of the *larger* [5] red Globules, and of the ſerous ones, and alſo know why the former are ſo *neceſſary* [6] in the Blood of a ſtrong healthy Perſon. In effect, thoſe Particles which we call cruor or red Blood, are the largeſt or groſſeſt of all the Homours that have their Birth and Inhabitance either in the Arteries, Veins, or any of the Viſcera of a Perſon in Health; the next that follow in Size, are thoſe of the yellowiſh Serum, which hardens with Heat; next come the colourleſs lymphatic

lymphatic Juices, which alſo congeal with Heat; then the limpid Humours not concreting by Heat with the Milk, Urine, and all others gradually decreaſing in the Size of their Particles, but not yet accurately claſſed or enumerated [7].

[7] The Texture of the Blood obſerved formerly by *Lewenhoec* has been ſince univerſally received among the Learned; and I have myſelf frequently confirmed the Truth of it by an infinite Number of Experiments. A little of the Blood that comes out of a Puncture in one's Finger, being firſt diluted with a Drop of Water to make it more pellucid, then taken up in a capillary Glaſs Tube and applied to a Microſcope, appears at the firſt View to be all red, but afterwards you may diſtinguiſh the red Globules in its Compoſition, ſwimming in the almoſt pellucid and aqueous Serum. Theſe red Globules loſe that Colour by ſtanding ſtill, even during your Obſervation; ſo that after a while you can perceive none but yellow Globules inſtead of the red ones, ſix of which yellow ones are equal to one of the red: *Lewenhoec* has not only often ſeen this Separation of the red Globules into the leſſer ſerous ones, but he has alſo ſeen the Combination of the ſerous ones together, by ſixes, into the larger red ones, in Fiſh and Inſects. But upon repeating your Obſervation after a longer Interval, you will perceive that all the yellow Globules are vaniſh'd, and that there now only remains pellucid and ſmaller Spherules, each ſix times leſs than the yellow or ſerous Globules, and thirty ſix times ſmaller than the red ones. Here the Eye is incapable of deſcending any farther into ſmaller Diviſions of theſe laſt Globules, but by Reaſon

Reaſon and Analogy we have ſome Foundation to believe that the more ſubtle Juices in the human Body are compoſed of ſtill ſmaller Globules, and that there are as many Series of decreaſing Globules as there are of the ſmaller Veſſels conveying the ſeveral Juices; and *Lewenhoec* affirms, he has ſeen ſome Veſſels in the Brain of 512 times leſs Diameter than the red Globules. We obſerve then that the largeſt Particles in the Blood are the red Globules, compoſed each of ſix yellow or ſerous ones; and if ever there were any larger than theſe, they are not healthy but morbid, and formed by the Coheſion of ſeveral red Globules together, as is obſervable in many acute Fevers. The Size or Magnitude of each red Globule is determined by the Diameter of the ſmalleſt ſanguiferous Arteries in the Lungs; as it is alſo probable the Sizes of the ſmaller ſerous ones are by the ſeveral Orders of lymphatic Arteries in the ſame Viſcus. When the larger red Globules paſſing through the Arteries are preſented to Orifices of their lateral Branches too ſmall to admit them, they then keep on their Courſe in the ſame Veſſel towards the ſanguiferous Vein into which it opens; while the ſmaller yellow and ſerous Globules enter into and paſs along the ſmall lateral Branches whoſe Orifices were impervious to the red ones. Again, when theſe ſerous Globules arrive at Orifices too ſmall for their Admittance in paſſing through their proper Artery, they will go on into their correſponding ſerous Vein, while the ſmaller, pellucid, and colourleſs lymphatic Globules will run off through the ſmaller Arteriolæ, whoſe Orifices refuſed the larger yellow or ſerous Globules; and in the ſame manner will the Courſe be carried on in their Paſſage through the lymphatic Arteries of the ſeveral Orders into their correſponding Veins.

2 It is remarkable, that in moſt of the Subſtances we uſe as Aliment there are large Globules diſcernable, of a lax Texture, and of different Sizes; which in the Chyle become leſs and more compact, or denſer and ſmother; and which in the Blood are again formed into ſtill more compact and larger Globules. *Vid.* §. 127.

3 From the Figure of the ſmalleſt Veſſels in the Lungs and Muſcles through which they are forcibly ſtrained, and from their equable Rotation and Attrition among the other ſimilar Spherules of the Blood itſelf.

4 The red Fluid we call Blood, which is the thickeſt or groſſeſt of any circulating in the human Body, contains the Materials of all the other Juices found in every Part of the Body; for the Serum comes from hence, in which is compriſed all the other Juices of the Body, except the Blood itſelf; and by dividing ſucceſſively into leſſer Particles it ſupplies all the Series of Veſſels, even to the moſt ſubtile Juice or Spirit of the Nerves. But the Serum is compoſed of Particles of different Magnitudes, whence the Milk paſſes through Veſſels which the Serum will not, ſince we do not obſerve the hardening Serum in the Milk. The ſame may be ſaid of the Saliva, Urine, *&c.*

5 The Stability or Permanence and Strength of the Body depends on the Blood and thicker Juices, which receive and impreſs the Force of the Heart upon the other finer Juices in the ſmaller Veſſels; thus the Blood moves or propells all the thinner Juices of the Body without entring into their ſmaller Veſſels itſelf; and in this manner one Series of Globules will protrude the next through the ſeveral Orders of Veſſels, and that too with a leſſer Force proportionable to the greater Thinneſs of their Coats or Sides, by which they will avoid

avoid Rupture. And thus too, one Humour will digeſt and prepare the next, throughout the ſeveral Series of Veſſels, from the thick Blood down to the ſubtile nervous Juice, or from the Time of their Ingeſtion till they are conſumed and expell'd in Form of an inviſible Vapour, after having performed all the Offices in the Body. For Example, in the White of an Egg, we are aſſured that from thence are formed all the different, ſolid, and fluid Parts of the Chick within the Space of three Weeks; and there is little or no Difference betwixt the Serum of the Blood and the White of an Egg: So that we may hence eaſily conceive the Serum ſufficient to ſupply all the ſeveral Juices of the Body, and differing in Texture or Fluidity, not excepting even thoſe which are volatile, and fly off into the Air. But this Change, either in the Serum or Albumen, is not made all at once but by a ſlow and gradual Attenuation, by which it is at laſt ſubtiliſed into the moſt fluid Juices of the minute and tender Chick. In the ſame manner we apprehend that the Serum is ſucceſſively attenuated and ſubtiliſed as it paſſes through all the ſeveral Orders of the ſerous Veſſels, whoſe Number we are unable to determine, till at length it is fit to nouriſh and pervade the minuteſt Receſſes of the Body; and perhaps this Change too of the Serum may be made in the like Space of three Weeks or twenty one Days; ſince the Serum and Albumen are ſo much alike in Subſtance, the Heat of the human Body but little leſs than that of a ſitting Hen, and the different Juices thence made in the Chick, the ſame with thoſe made in the human Species, Lymph, Bile, *&c.* 'Tis even a Queſtion, whether the Menſes in Women do not ariſe from this Quarter, ſince they generally become plethoric in the like Space of about twenty one Days,

Days, on which see more at §. 659, following. But was this great Attenuation of the Juices, from their Ingestion to their Exhalation, to be made suddenly, or in a short time, the whole Body would be quickly lost insensibly in Vapours; to prevent this therefore, the wise Architect has framed our Blood and Serum, with a certain necessary Degree of Firmness, and order'd it to pass through several Series (the Number of which we know not) of minute Vessels, each smaller than the other. Lastly, it is from the largest sized, or red Particles of the Blood that its Heat arises (*per* §. 220, N° 13.) for the other Juices in its Composition, notwithstanding their Motion, do not generate Heat; so that those Parts of the Body are coldest where the red or sanguiferous Arteries are fewest, as in the Substance of the Brain, *&c.*

[6] For the Vibrations and Concussions of these spherical Machines are almost as necessary for digesting and farther attenuating the Chyle as those of the elastic Fibres and Arteries themselves; so that when the Blood is once impoverish'd or become too serous, it is then over with the necessary Digestion of the Chyle in the Blood previous to all the other Functions; or as *Hippocrates* says, "When our Aliments are too tough or strong, "they breed Diseases; when too weak or lax, "they will not sustain their Office."

§. 227. From what we have before delivered you may easily conclude what Judgment one ought to form concerning the *Galenical* [1] and *Chemical* [2] Doctrine advanced to explain the Nature of the Blood.

[1] *Galen* and his Followers gave the Name of Blood to all that red Liquor contained in the Ar-

teries and Veins, which they distinguished into four Sorts of Particles or Humours: Blood, more strictly so called, as giving the red Colour to the whole Mass; yellow Bile, or the Serum in which the Crassamentum swims; Phlegm, or the pellucid Liquor into which the yellow Bile or Serum changes by standing; and lastly, the Atrabilis lying at the Bottom of the Vessel, being only the heaviest and darkest Part of the Crassamentum. From a Mixture of these four Humours in due Proportion, say they, arises the most healthy Constitution of the Body; but when any of them are predominant above the rest, they will occasion some of the Temperaments of §. 228.— But from the preceding microscopical Observations of *Lewenhoec*, it readily appears, that the Crassamentum is nothing more than an Assemblage of Globules cohering in one Mass; and that the yellow Bile is only the Serum without any Bitterness, since there is never any Bile observed in healthy Blood, for if any be found there it is morbid and occasions a Jaundice. Their Phlegm too is no more than the Serum whose yellow Globules are dissolved into lesser pellucid ones by standing; but their Atrabilis is truly a Part of the Crassamentum, or the largest and heaviest, or the most compact of the red Globules, which therefore sink lower than the rest and appear of a darker Colour.

[2] The noted *Basil Valentine*, of whom we can only learn that he was a *Benedictine* Monk in the Monastery of *Erford*, (though we are much indebted to him for his early Dissertations in Chemistry, and know that he must have lived after *J. B. Carpensis*, because he directs to cure the venereal Disease with Mercury) was the first who taught that the Blood consisted of Salt, Sulphur, and Mercury; in which Doctrine he was followed by

Paracelsus

Paracelſus and many others. By the Mercury they underſtood the volatile and aqueous Parts of the Blood, and by Sulphur, its oily Parts; taking no Notice of its earthy Parts, which are very different from the ſaline, and plentifully contained in the Blood, as we know from its being uſed in the making of Teſts for refining Metals. There are other Chemiſts again who teach us that thoſe are the genuine Principles of the Blood which it affords by an intenſe Fire; *viz.* Oil, a volatile alcaline Salt, Water, and Earth. Thus if recent Blood be expoſed in a Retort to a Heat of 100 gr. in *Balneo Mariæ*, there comes over firſt an inſipid Water, almoſt to half the Quantity with the Blood; then with a ſtronger Heat comes over more Water impregnated with Oil a little, and a fœtid Smell; and by increaſing your Heat above 276 gr. you obtain a ſtrong and pungent Liquor or Spirit compounded of a volatile alcaline Salt, Oil, and Phlegm; after that a volatile alcaline Salt ariſes in a dry Form, follow'd with an empyreumatic yellow Oil; and laſt of all, your ſtrongeſt Heat raiſes a more ponderous and thick Oil than the preceding (which if obſtructed in its Paſſage through the Neck of the Retort by Cold or otherwiſe, it never fails to burſt the Veſſels) leaving a black duſty Subſtance like a Coal in the Bottom of the Retort. But all theſe acrid Salts and Oils are the Produce of the Fire, and not the natural Principles of the Blood; for if ſuch were contained in the circulating Juices of our tender Veſſels we ſhould be ſoon deſtroyed, or our Veſſels diſſolved, even before our Birth: And beſides, if you return and mix them all together again into one Maſs, they form a Compoſt in every reſpect foreign and diſſimilar to the Blood; and therefore this is not the way to acquire a juſt Knowledge of the natural Elements or conſtituent

Principles of this animal Fluid. As theſe Principles are unjuſt, the Explication of the Blood's Nature derived from them will be equally groundleſs; for its red Colour is not cauſed by any Sulphur, but a Condenſation or Combination of the Globules. If you nouriſh a cachetic Girl even with an Egg Diet, ſhe will not improve the florid Colour of her Blood; but if you only feed her with mere Bread and Water, and add repeated Exerciſe to it, ſhe will both recover the Redneſs of her Blood and the freſh Colour of her Cheeks.

§. 228. And from what has been advanced too, you may perhaps diſcern that the various Conditions of the Blood in different People, and the uſual *Temperaments* [1] thence deduced, are much better derived from its component aqueous, oily, ſaline, and earthy *Parts* [2].

[1] The Ancients reckoned as many Temperaments as Humours; *viz.* phlegmatic, choleric, melancholic, and ſanguine, with their Subdiviſions or Combinations, reſulting from two or more of their Humours being predominant in the Blood (*per.* §. 227, N° 1.); but if their Doctrines ought to be rejected, the chemical ones deſerve to be much more ſo.

[2] Water ſo much abounds in all our Blood and Juices, that it is doubtleſs the chief Principle or Element throughout the whole Body; and even the Solids themſelves are derived from the Fluids, and afford an extraordinary Quantity of Water by various Experiments. Earth makes the Baſis or leaſt and rigid Particles of the Solids; and Oil manifeſts itſelf abundantly in the Fat or cellular Membrane, as well as in the Blood by the Microſcope: And that

that there are Salts in the Blood appears too not only from the Microſcope (*per* §. 224, N° 5.) but alſo from the acrid and deterſive Quality of the Bile (§. 99, N° 2.) and Saliva (§. 66, N° 9.) *&c.* But though the human Salts are alcaleſcent, they are not naturally alcaline, but come neareſt to Sal Ammoniacum; and whatever Principles we obſerve in any of the Juices they muſt have been firſt in the Blood, as all the Juices are thence derived. Hence then we conclude, that there are Particles of Water, Earth, Salt, and Oil circulating in the red Blood through the ſmall Veſſels of our Bodies; the different Quantities and Qualities of which will equally account for all the Appearances attributed by the Ancients to their ſeveral Humours and Temperaments. When Water is redundant it will produce Relaxation, dropſical Tumours, Coldneſs, Paleneſs, and Weakneſs; when Salts abound, the Juices will be too acrid, ſtimulating and eroding, will excite the Circulation, cauſe ſudden Pains, and a high colour'd Urine; when Earth abounds the Juices will be too ſluggiſh and groſs, will excite Drowth, Leanneſs, Melancholy or Sadneſs, and Immobility; and when Oil is redundant the Perſon will be fat and unactive, and the Juices will be viſcid, cold, and impervious. But to account juſtly for theſe Variations of Habit, the State of the Solids muſt be conſider'd as well as of the Fluids; *per* §. 890.

§. 229. Finally, it is alſo evident from Experience, that the Blood's circulatory *Motion only* [1], cauſes and preſerves its uniform Mixture, *Fluidity* [2], Heat, and Redneſs; ſince theſe Effects are either abſent, or more or leſs

preſent, as that Motion is either deſtroy'd, augmented, or decreaſed.

[1] The Blood when at reſt or out of the Veſſels, ſeparates naturally into three different Parts, a vapory, a ſerous, and a craſſamentum; but theſe conſtituent Parts do not depart from each other while it circulates with Motion enough in the Veſſels. The ſame extravaſated Blood alſo putrifies with a Heat of 90 gr. in the Space of three Days time, ſo as to exhale a moſt intolerable or offenſive Stench; but by the Continuance of this circulatory Motion it will continue ſound in the ſame Degree of Heat as long as the Animal is alive and well. Therefore the ſound and healthy State of the Blood does not depend primarily on its conſtituent Principles but on this circulatory Motion.

[2] After the Blood has been extravaſated a few Hours, its uniform Redneſs is for the moſt part changed into a yellow Liquor we call Serum, which being decanted from the Craſſamentum, more Serum again flows from it, till at length the whole Maſs is converted into that Liquor, leaving only a ſmall Quantity of a grumous Subſtance behind: In the ſame manner will the firm Texture of the Blood diſſolve and become ſerous in a leſs degree by a too ſlow Motion in the Body; ſo that by too much Reſt or Inactivity, we ſhall either look pale, yellow, or green, from the Condition of our Blood and its Juices, as may be frequently obſerved in Women and Children. Upon this Account too Mr. *Boyle* and Dr. *Bohnius* never preſumed to determine the Proportion betwixt the Serum and Craſſamentum, becauſe they obſerved more of either at one time than at another. The Redneſs and Compactneſs of the Blood therefore increaſes as its Motion, by whoſe Intenſity its Surface will be

ſome

ſometimes ſpread with a whitiſh and tough Skin, like that of Trotters or Neats-feet, as may be frequently obſerved in the Blood of pleuretic Patients; and in Proportion as the Blood acquires more of this Thickneſs, ſo its Heat gradually increaſes, as we are taught by *Farenheit*'s Thermometer.

§. 230. Having thus ſurvey'd the Origin and Nature of the Blood and Chyle, it will be our next Buſineſs to examine what Alterations they undergo, as they are propell'd by the Force of the Heart and Arteries into the ſmall capillary Veſſels, ſpent in the Glands, Muſcles, Emunctories, and Viſcera: But of all theſe the Encephalon or Brain and its Appendages, deſerves the firſt Conſideration, as well becauſe it receives the Blood from the Heart before any of the reſt, as from its more immediate Concern in the Support of Life.

The Courſe and Action of the Arteries diſtributed to the Cerebrum and Cerebellum.

§. 231. BUT before we examine the Brain itſelf, we muſt firſt conſider the Origin and Courſe of its *carotid* [1] Arteries. Obſerve therefore that the Aorta having aſcended a little above its Origin from the left Ventricle of the Heart, paſſes out of the Peri-

cardium, and is ſoon after bent in Form of an *Arch* [2] or Curvature, from the right Side of which ſpring the *ſubclavian* [3] and right Carotid, which are conjoined in one for a little way, as if the latter aroſe from the former; but the left Carotid ariſes ſingle from the Arch itſelf, from whence the two Carotids proceed in a very even or direct Courſe to the Cranium, in paſſing to which they are *defended* [4] by the Aſpera Arteria and their deep Situation, without undergoing any Preſſure or Incurvations, and hardly ever affording any *Branches* [5] by the way: Having almoſt reached the Cranium, they each of them ſend off an *external* [6] Carotid, and then entring thro' a bony *Channel* [7] in which they are ſecured, they are inflected therein forwards, put off their fourth or muſcular Tunic (§. 132.) and give Branches to the Dura Mater; withinſide the Cranium they are each again *defended* [8] by the Sides of the Sella Turcica, and a Proceſs of the Dura Mater, and then expanding themſelves on the Surface of the Pia Mater and Nerves, they divide into anterior, poſterior, and lateral Branches, which are by means of the Pia Mater inſerted into the Brain itſelf.

[1] Their Name is generally ſuppoſed to be derived from Καρας, *Somnus*; becauſe *Galen* deduces that Denomination of them from the Experiment of *Eraſiſtratus*, *viz.* that upon making a Ligature on them the Animal falls into a Carus or Drowſineſs.

[2] In

[2] In Brutes who have long and pendulous Necks the Aorta divides into an aſcending and deſcending Trunk; and Anatomiſts having taken their Figures of the Aorta either from them or from one another, has occaſioned the Error of an aſcending Trunk to be exhibited in moſt of their Books and Figures; none of them having given us a true Idea of the human Aorta except *Euſtachius*, *Caſſerius*, *Lower*, and *Ruyſch*.

[3] The right ſubclavian Artery is both nearer the Heart and of a larger Diameter than the left, whence it is that moſt People uſe their right Hand more than the left, as being from hence naturally ſtronger; but if the ſubclavian Arteries are both of equal Diameters, then the Perſon will be *ambidexter*; or if the left Subclavian be larger than the right, which ſeldom happens, then the left Hand will be more active and ſtrong than the right.

[4] The Windpipe projects out ſo far as to hinder any Compreſſure from reaching the carotid Arteries; whence it is that the Blood has a free Courſe to the Brain, by the Carotids, in thoſe who are hanged and ſtrangled with a Cord: But the jugular Veins lying but juſt under the Skin are ſo ſtrictly compreſſed by the Ligature that no Blood can return by them, while the very little compreſſed Carotid and uncompreſſed vertebral Arteries (§. 232.) continue to urge the Blood on to the Brain, as in an Apoplexy.

[5] You will not perhaps meet with any other Artery in the whole human Body that runs to ſuch a Length as the Carotids without ſending off any Branches.

[6] The Blood is not abſolutely of the ſame Nature in the external as in the internal carotid Artery, but undergoes a Kind of Separation or Preparation

(*per*

(*per* §. 224.) according to the Diſpoſition of each Artery in order to Secretion.

7 To the Sides of which they grow, and are very firmly attached, ſo that they cannot be ever too much or too little diſtended in this Part, becauſe the long Canal always keeps them in the ſame Diameter. In conſumptive People, the whole Maſs of Blood is frequently almoſt conſumed to a few Ounces, but the internal Carotids are nevertheleſs equally full, from their Diameter being ſuſtained by theſe bony Channels; whence the Senſes and Intellects of ſuch pthiſical Patients are generally ſound and entire, even to the End of their Lives, notwithſtanding the vaſt Decay in all the other Parts and their Functions.

8 The Dura Mater is firmly extended over the carotid Artery, as the Membrane is expanded over the Tympanum, that the Weight of the ſuperincumbent Brain might not compreſs the ſame upon jumping, dancing, or any ſudden Shock.

§. 232. But the vertebral Arteries ariſing from the upper Part of the Subclavians, aſcend and ſoon enter the lateral Foramina of the ſeven Vertebræ of the Neck in which they are received, *defended* [1], continued directly forwards and ſecured with a vaginal Membrane or Integument, giving *Branches* [2] as they go, and when they emerge out of the Foramina of the Vertebræ, they are immediately after *incurvated* [3] and inflected under and behind the upper Proceſſes of the Atlas or *firſt* [4] Vertebra, and becoming there ſomewhat enlarged, they then enter through the great Foramen of the Occiput, where depoſiting their

their thick muſcular Coat, they afterwards unite and become much more capacious than before, and after communicating with the Carotids, they are then ſurpriſingly ramified or *divided* [5] into Branches.

[1] Nature has been much more ſolicitous to defend and ſecure the vertebral than the carotid Arteries from any Violence or Compreſſure; becauſe the firſt convey Blood to the Cerebellum, upon whoſe uninterrupted Action Life, or the Motion of the Heart, immediately depends: But the carotid Arteries being ſpent on the Cerebrum, a Preſſure in them is not ſo imminently fatal, producing only a Carus, Lethargy, *&c.* according to the Degree of Obſtruction.

[2] In every Space betwixt each of the Vertebræ they ſend out an arterial Circle or Branch, into which the leſs moveable Particles of the Blood have a greater Tendence, *per* §. 224.

[3] By theſe Incurvations the ſame Effect is obtained as if the Neck was made longer; *i. e.* the Interval and Reſiſtance betwixt the Heart and Brain is thus increaſed.

[4] In the firſt Vertebra or Atlas there is a Notch, through which paſſes the vertebral Artery, on each Side; but ſometimes this Notch is formed into a compleat Ring or Foramen, as you may obſerve in the Skeleton of our *Leyden* Theatre, prepared by the famous *Vander Weil*; in which there is a compleat Canal in each Side the Atlas for the vertebral Arteries to paſs through before they enter the great Foramen of the Occiput.

[5] They particularly ſend off Branches call'd the Spinal Arteries, which deſcend on the fore and back Part of the Spinal Medulla, even down to

Os

Os Coccygis: So that after the Blood has aſcended by the vertebral Arteries to the Occiput, it again deſcends in a retrograde Courſe down the ſpinal Arteries twice as far as it aſcended by the vertebral.

§. 233. We have therefore four Arteries (§. 231, 232.) aſcending from oppoſite Sides, and mutually opening into each other in the Cranium, ſo as to form a ſort of arterial *Circle* [1], from whence Branches are immediately detached, which meeting together and inoſculating in the ſame manner, form leſſer arterial Circles of the like *Kind* [2], in which Courſe they are again ſubdivided upon the whole Superficies of the Pia Mater, till they at laſt *diſappear* [3] or eſcape the Eye, inſomuch that the whole Membrane or Pia Mater ſeems to be made up chiefly by ſuch a Contexture of Arteries.

[1] By the arterial Circle, which is formed by the Union of the ſingle or common Trunk of the vertebral Arteries with the two Carotids, the Encephalon is entirely preſerved from dangerous Obſtructions: For as no leſs than four Arteries conjoin to form that Circle, the Paſſage through three of them may be entirely obſtructed, and yet the Brain and Cerebellum will be all over ſupply'd with Blood by the fourth; nor do we know of the like advantageous Mechaniſm in any other Part of the Body.

[2] From the firſt or preceding arterial Circle ariſe perpendicular Arteries on all Sides, which inoſculating with each other's lateral Branches, form leſſer

leſſer arterial Circles, from whence again ſpring other leſſer perpendicular Arteriolæ, which again form ſtill ſmaller Circles and lateral Branches as before, even to the ſmalleſt which eſcape the Sight.

[3] We before obſerved, that the Arteries of the Brain depoſit their thick muſcular Coat before they enter the Cranium (§. 231.); and when arrived within the Cranium they again depoſit the outermoſt of their remaining Coats which forms the Tunica Arachnoides, under which, the ſmaller Arteries, now conſiſting of but one thin Coat, are diſperſed into an infinite Number of ſmall Circles and Plexus's, which form that membranous Network of Veſſels we call the Pia Mater, from which the very ſmalleſt of the Arteriolæ are detached into the cortical Subſtance of the Brain itſelf. *Vid.* §. 236.

§. 234. All the Blood therefore which is ſent from the Heart to the Brain, is, by this mechanical Diſpoſition of the Arteries, convey'd firſt to its thin Membrane the Pia Mater, from whence it paſſes into the Subſtance both of the Cerebrum and Cerebellum: For what other Blood is ſent into the Cranium belongs only to the *Dura Mater* [1] of the Cerebrum and Cerebellum, and is brought thither chiefly by two Arteries which ſpring from the external Carotids, and enter each through a diſtinct Hole of the Skull, diſtributing themſelves laterally; to theſe add the Branches which come from the internal Carotids, thro' their Canalis Oſſeus, and ſpread themſelves on the anterior Part of the Dura Mater; with

thoſe

thoſe from the external Vertebrals, entring through the bony Duct of the Jugulars, and expanding themſelves on the back Part of the Dura Mater; all which have been demonſtrated by the accurate Repletion of theſe Veſſels with ceraceous Injection by *Raw*[2], who was well verſed in that Artifice. On the Account of theſe Arteries, the Dura Mater is furniſh'd with ſtrong Fibres next the Brain, to break off and ſuſtain the Impulſe of the Blood in its Arteries, and prevent any Injury from ariſing thence to ſo tender and important a Viſcus. Laſtly, the whole internal Surface of this robuſt Integument is lubricated, and prevented from adhering to the Pia Mater by a kind of ſerous or lymphatic Dew, which exhales not only in this but in all the other Interſtices of the Body.

[1] There are two Sorts of Arteries within the Cranium; ſome which have a ſtrong Pulſation like the other Arteries of the Body, and others, which, having depoſited their muſcular Coat, in a manner ceaſe to be Arteries, and form a ſort of intermediate Veſſels betwixt an Artery and a Vein, having very little Motion, and uniting with each other into Plexus's like the Veins: But then theſe two Kinds of Arteries remain very diſtinct from each other, and have no Communication but in the Heart; for the beating Arteries are diſtributed to the Dura Mater only, while the ſoft venal Arteries are ſpent upon the cortical Subſtance of the Cerebrum or Cerebellum.

[2] The Arteries of the Dura Mater are chiefly the three before-mentioned, one from the external Carotid,

Carotid, which comes to the Dura Mater through the ſixth Hole of the Cranium; a ſecond from the internal Carotid, as it comes through its Canalis Oſſeus, and a third from the vertebral Arteries, without the Skull: All which Arteries have no Communication either with the cortical Part of the Brain or Cerebellum. But the indefatigable *Vieuſſens* has affirmed, that the Blood paſſes from the Arteries of the Dura Mater into the longitudinal Sinus; which he ſays is a Piece of Conduct in Nature to render the venal Blood of the Sinus more fluid and leſs apt to coagulate: And adds, that he injected Ink and coloured Spirit of Wine by the carotid Arteries, in the Preſence of ſeveral Phyſicians incredulous of his Opinion, which Liquors paſſed into the Sinus's. To be ſatisfied in this reſpect I deſired my Friend *Ruyſch* to repeat the Experiment; in conſequence of which he injected the carotid Arteries ſo exquiſitely as to force his Wax through the ſmall Arteries into their correſponding Veins, which open into the Sinus, into which the Injection had been ſtrained through the ſmall Anaſtomoſes, ſo as to have none of its Pigment or Colour when it arrived in the Sinus's. This was therefore the way through which the Liquors injected by *Vieuſſens* had paſſed, *i. e.* thro' the Anaſtomoſes of the Veins, and not immediately from the Arteries into the Sinus's. And in the Injection made by *Ruyſch* there were found continuous Cylinders of the Wax in the Anaſtomoſes of the Arteries and Veins of the Dura Mater. *Raw* made the like Experiment at my Requeſt, but could find no immediate Opening of the Arteries into any of the Sinus's.

§. 235. From this Courſe of the Veſſels (§. 231 to 234. and the Nature of the Blood, §. 224.

§. 224. whoſe Parts ſtrictly obſerve that Rule of Motion) we may plainly perceive that the Blood arrives both in oppoſite Courſes to the Brain, and in a more homogeneous and refined State than to other Parts; becauſe as it approaches the Baſis of the Cranium, it is there freed from the viſcid Matter of the Saliva and *mucous Juices* [1]; and the Blood of the vertebral Arteries will be more pure or leſs viſcid by detaching the like Particles into its *lateral Arteries* [2], while its more groſs and ponderous Parts will be alſo repell'd by the *Inflections* [3] in both the Carotids and Vertebrals; and again the Blood will be freed from its leſs moveable Parts in the *Caverns* [4] formed by the Dura Mater at the Sides of the Sella Turcica, and the remaining groſſer Parts will be ſent to the Infundibulum and *Integuments* [5] of the ten Pair of Nerves: From all which it follows (1.) that the Blood arriving by the Veſſels (§. 223.) in *oppoſite Directions* [6], will impinge on that already in thoſe Veſſels, and retaining its original Nature, or having acquired one more refined, its Impetus will be ſo far *abated* [7] as to hinder its compreſſing the ſoft and pulpy Subſtance of the Encephalon; (2.) will follow an intimate Commixture of all Blood brought hither, ſo as to become uniformly alike in every Part of it; (3.) an Attenuation, Levigation, and Attrition of its Parts, an Increaſe of their Fluidity, a Prevention of their concreting, and an Aptitude or Diſpoſition of them for the ſubſequent Secretion; (4.) a leſs

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Dilatation [8] or Pulse of the Arteries here, and a less Re-action of them on the Blood than in other Parts of the Body; and lastly, (5.) a Compensation for the Inactivity or Unaptitude of these large and small Vessels to transmit their Contents, by their inosculating so abundantly with each other, as gives the Blood a free *Course* [9] from any one Vessel to the rest in all manner of Directions.

[1] For since the external carotid Artery arises or goes off laterally from the common Trunk, it will be most disposed to receive those Parts of the Blood which are least apt to retain their rectilineal Motion; and such are the Particles secerned by the four larger salival Glands, with the Mucus separated in the Membrana Schneideriana.

[2] Many Branches of the vertebral Arteries are reflected back or downward, and others go off at right Angles, both which will receive the less moveable Parts of the Blood, and separate from thence that fat Mucus which invests the spinal Medulla; therefore the more light, moveable, and spherical Particles of the Blood in the vertebral Trunks will go forwards or upwards to the Brain, while the more viscid and sluggish Parts recede from it into the lateral and retrograde Branches. I do not intend you should understand that all the smallest Particles of every kind in the Blood are thus convey'd to the Brain; but the smallest Parts which are dense and similar to each other, the smallest of the red Globules, the smallest of the serous ones, *&c.* *Vid.* §. 220 and 224.

[3] The carotid Arteries are inflected as they pass through the Canal in each Os Petrosum, and the Vertebrals are inflected at their Ingress into the

Cranium ; both whoſe Inflections diminiſh the Impetus of the Blood brought to the Encephalon, and prevent it from ruſhing too impetuouſly upon the ſoft cortical Subſtance ; at the ſame time alſo, theſe Inflections augment the Length of the Canals, and increaſe their Diſtance from the Heart, ſo as to diminiſh the Impulſe of the laſt.

4 When the Blood of the carotid Arteries has paſſed into the Cranium, it again meets with another Inflection or Remora in theſe Caverns, where it alſo enters a Set of ſmall Arteries expanded and interwove like a fine Net, whence it has been denominated Rete mirabile, being by much the moſt conſpicuous in Brutes ; into which Plexus are detached the more ſluggiſh Parts of the Blood, whoſe Impetus or Velocity is here abated.

5 The vaginal Integument of the Nerves, coming from the Pia Mater, receives Branches of the carotid and vertebral Arteries, which appear very red and conſpicuous by Injection.

6 There are many Advantages attending this mutual Intercourſe of the Blood in oppoſite Directions ; for it will by this means obtain an intimate Mixture and Attrition of Parts (*per* §. 220. N° 3, 4.) by which they will be attenuated and rendered more fluid, ſo as to prevent any Grumes or Concretions, to which the Blood would be otherwiſe very liable in its Paſſage through ſo very ſmall Veſſels unagitated by any Muſcles, and even without the Action of a muſcular Coat, obſerved in all the other Arteries. Another Advantage is the Diverſion of the Blood's Impulſe and Velocity from injuring the tender Subſtance of the Brain ; to abate which nothing can be more effectual than the many Inflections, lateral Ramifications, mutual and infinite Inoſculations of ſmall Veſſels exerting little or no Re-action ; by which means the Blood will loſe much

much of its Force againſt the Sides of the Veſſels, and againſt the other Blood which meets it in oppoſite Courſes. *Vid.* §. 215. N° 2.

7 That the tender cortical Veſſels might not be broke or over-ſtrained beyond their Tone or Elaſticity by too great an Impulſe of the Blood; for the entire Serenity or right Compoſure of the Mind depends altogether on the Arteries of the Brain reſiſting the Impulſe of the Blood to a proper Degree; below which, a leſs Reſiſtance confounds the Mind and diſorders its Faculties. *Peyerus* having ty'd one of the jugular Veins in a Dog, he ſoon after became ſtupid, and made many odd ſporting Geſtures, till at laſt he fell into a dead Sleep, from a too great Diſtention of the Blood-veſſels in the Brain; from which Cauſe alone, in various Degrees, may be produced all the ſeveral Diſorders of the Brain. And a too great Plenitude of the Veſſels in the Brain, from a Stoppage of any Evacuation, will have the ſame Effects. Thoſe who either die phrenitic or ſtrangled have the Blood-veſſels of the Pia Mater ſo turgid and full that they are ready to burſt. To prevent ſuch a Redundance and too great Impulſe of the Blood on the Brain, Nature has uſed many Precautions; the Inflection of the Trunks, the Diviſion of them into lateral Branches, and the Subdiviſion of their ſmaller Branches within the Cranium into ſeveral Series, which inoſculate together, and expand themſelves circularly about the Brain before they enter its cortical Subſtance. Headachs which very eaſily ſupervene a little increaſe of Exerciſe or muſcular Motion demonſtrate that theſe Veſſels are in danger of a Rupture.

8 I was formerly ſeduced, by the ſpecious Arguments of *Baglivi* and *Pacchioni*, to think that theſe Arteries had a Pulſation like the reſt in the Body;

but I know, by Experiment, that the Arteries of the Brain have not a Syſtole and Diaſtole like others, nor are they fill'd alternately, but continue equally and moderately diſtended; for ſo ſoon as they begin to beat or vibrate, the Senſes are conſtantly diſordered. I took off the Top of the Cranium in a living Dog, and could then ſee the Arteries of the Dura Mater vibrating ſo ſtrongly as might well impreſs their Figure on the ſolid Plates of the Skull; for ſuch was their Motion, that they agitated both the Dura Mater and its Sinus's, as if they had a Pulſation in themſelves: But upon removing the Dura Mater, the Brain appeared quiet with diſtended Arteries, but without any Pulſation; at which ſeveral learned Spectators of *Baglivi*'s Opinion were highly ſurpriſed, ſince they expected to ſee the whole Brain jump up at every Syſtole of the Heart.

9 From hence it is that Wax being injected by one Artery of the Brain, it runs into all the reſt. From this Principle too, no one Part of the Brain will be more preſſed than another; for if the Blood aſcends more forcibly by the carotid than by the vertebral Artery, it will not preſs ſtronger on any Part of the Brain than the vertebral, by means of their Communication with each other, whence every Part of the Brain will be equally ſupplied with Blood, and one Part will receive as much Spirits as another. From hence too it is that a Man may live notwithſtanding, his carotid Arteries are obſtructed or become oſſified, ſo as to be unable to propell the Blood; for then the vertebral Arteries will convey more Blood than before, and propell it both into the Carotids and into the whole Surface of the Brain: Whence alſo, when one Part of the Cortex is deſtroy'd, ſuppurated, or loaded with a Fungus, none of the Functions

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are thence injured, becauſe the remaining Veſſels of the next adjacent Stratum of the Cortex ſupply the Defect; for the Cortex of the Brain is compoſed of an infinite Number of Lamellæ or Strata of ſmall arterial Veſſels, the largeſt of which lie outermoſt, and under them ſmaller, till you come to the laſt Stratum of the ſmalleſt of theſe Veſſels, under perhaps a thouſand of the larger, from which laſt Stratum ariſes the Medulla of the Brain. So that if you remove all the outermoſt Strata from a Part of the Cortex, and leave only that which is next the Medulla, the adjacent Strata will then ſupply this laſt by their infinite Anaſtomoſes continuing all the way from one Stratum to another beneath the firſt, ſo that the Secretion will be no where loſt, but the whole Origin of the Nerves will be ſupplied with their Juices.

§. 236. Now theſe Arteries of the Brain being thus interwove, and ſecured in Order (§. 233.) in the Pia Mater, as in a Stratum or Baſis which is incredibly thin, and like a *Spider's Web* [1], do, from every Point of the ſaid Membrane, detach ſmall arterial Branches almoſt in a perpendicular Courſe, which winding and inoſculating with each other like the firſt, form, as it were, a Membrane, by whoſe Inſinuation the external Subſtance of the Brain and Cerebellum is divided into winding *Furrows* and *Ridges* [2], ſo deep as to reach almoſt down to the *Medulla* [3]; only the Sulci or Furrows in the Cerebellum are not near ſo deep as thoſe in the Brain. But theſe Ridges, convoluted in the Form of Inteſtines, are again reſolvable into leſſer ones,

like the former, being all of them framed by the Inſinuation of the Pia Mater, and appear to contain red or ſanguiferous Veſſels only [4] in their exterior Surface, which Veſſels they convey to the Surface of their ſubjacent or included Subſtance. But then this included *Subſtance* [5] of the Ridges, which makes up the greateſt Part of them, never receives any ſanguiferous Artery or Vein, nor could it ever be injected or tinged of a red Colour; and as for that Part of this Subſtance which remains after macerating Portions of the Cerebrum and Cerebellum in Water, having firſt filled their Veſſels with ceraceous Injection, and freed them by Abraſion or ſhaking from the ſaid Subſtance, it appears like a Congeries of minute Vaſcules in Form of Down or fine Wool, which are ſo ſoft, juicy, and tender, as to break with the leaſt Force imaginable, and diſſolve into a purulent or *pulpy* [6] Juice, barely by ſuſpending them in ſimple Water.

[4] Whence the external Lamen of this Pia Mater, formed by the Depoſition of the more denſe Membranes of Tunics of its ſmall Veſſels, is uſually denominated Arachnoides Tunica, which is ſaid to be deſtitute of Veſſels; at leaſt it has none that we can diſcover either by the Eye or Injections. But I am certain there is no other Membrane under the Arachnoides beſides the ſmall Veſſels themſelves, which are interwove into a very thin Covering inveſting the cortical Subſtance, being almoſt as fine and much weaker than the Web of

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ſome Spiders. In a Word, the Pia Mater is the firſt Stratum of Arteries belonging to the Cortex of the Brain; and the Cortex itſelf is an infinite Number of pellucid, arterial Strata from the Pia Mater, containing one within the other.

[2] Theſe Gyri or Convolutions in the Brain have ſeveral Uſes or Advantages; as (1.) to increaſe the Surface of the cortical Subſtance, and conſequently its Secretion; (2) to bring the Cortex into Contact on all Sides with the medullary Fibrils or Tubuli, that its laſt Series of Veſſels may diſcharge themſelves with more Certainty into the ſaid Tubuli or Fibrils of the Medulla.

[3] The Ancients took the Pia Mater not for a Part of the Brain, but only for its interior Capſule, and the Dura Mater for its exterior Capſule, *Ruyſch* has demonſtrated to us, that the Pia Mater is inſerted on all Sides of the Brain down to the Bottom of its Sulci, from whence it riſes up again to cover the next Ridge: And in this manner it deſcends from the Top of one Hemiſphere of the Brain, and, after reaching the Corpus Calloſum, it returns up to the Top of the other Hemiſphere.

[4] This is ſufficiently proved in the Brain of ſuch as have been hanged, in which the Blood being impelled into the Arteries of the Pia Mater with the whole Force of the Heart, and being obſtructed in its Return by the Veins, renders the Blood-veſſels as full and turgid as if they had been injected: But even in ſuch we never obſerve any red Blood in the cortical Subſtance of the Brain, but its Progreſs is confined within the Veſſels of the Pia Mater.

[5] The celebrated *Ruyſch* having moderately fill'd the Arteries of the Brain with ceraceous Injection, by the Carotids, he then opened the Dura Mater,

and took out the injected Brain, whose cortical Surface appeared red only in some Parts, not all over. He took a Part of this Cortex with its injected Artery and macerated them in warm Water till a Putrifaction began to appear, and then gently and frequently shook the Mass in the Water to separate the Tunica Arachnoidea; which Operation he repeated till the Water became foul with the infinite Number of small white Flocculi washed off from the cortical Substance; but when the Water appeared no longer foul, retaining its original Clearness, he then removed the unravell'd Cortex, and suspended it in Alcohol Vini, in which it appeared like a little red Fleece of fine Down or Wool, being only a Bunch of the small arterial Vessels fill'd with the Injection. Thus all the small Vascules which were not entred by the Injection were dissolved and lost in the Water, and those only remained sound and entire which the Injection sustained and preserved from Corruption; so that all the venal and smallest arterial Fabric of the Cortex was thus destroy'd: But as many of the small Arteries thus preserved and injected are found to be fifty and a hundred times smaller than a Hair of one's Head, how vastly smaller must those be which were dissolved and washed away, as being impervious to the Injection. Nor does this Artifice demonstrate to us the true Nature and Mechanism of the Cortex, since the greatest Number of the Vessels are thus destroy'd, and the Remainder dislocated or unravell'd. It is observable that *Ruysch* only used the Heads of immature Fœtus's, or of new-born Infants for these Preparations.

[6] Being assisted by the Experiments of *Ruysch* and *Lewenhoec*, I can now boldly assert, that the Blood does not circulate through the internal Substance of the Cortex of the Brain, notwithstanding there

there are ſo many ſanguiferous Arteries and Veins ſpread on its Superficies; for the red Parts of the Blood only circulate in the Veſſels of the Pia Mater, the internal Part of the Cortex next the Brain being quite pellucid. This is true, notwithſtanding there are ſome ſanguiferous Veſſels obſervable in the medullary Part of the Brain, which perforate the Cortex and Medulla perpendicularly from the Pia Mater, without ſpreading into Branches, and ſeem deſigned to communicate Warmth to this Part. I deſired *Lewenhoec* to examine the cortical Part of the Brain with his Microſcope; but his Anſwer was, that he could ſee nothing but pellucid Globules. And *Ruyſch*, by his forementioned Preparation, has demonſtrated that the cortical Subſtance is a Congeries of ſmall pellucid Vaſcules like fine Wool, continued from the interior Blood-veſſels of the Pia Mater. It follows then that the Cortex is compoſed of Vaſcules continuous with thoſe of the Pia Mater, which admit only pellucid Parts of the Blood, and diſpoſed in Courſes not yet known. We know that the ſmall Veſſels are diſtributed in a different Courſe in every particular Part of the Body; and no doubt but they have a diſtinct and different Poſition in the cortical Subſtance of the Brain, tho' their Minuteneſs and Pellucidity conceal the ſame from our Eyes. But this we may reaſonably conclude, that they retain the ſame Diſpoſition in every Brain; for if they varied in this reſpect the reaſonable Faculties of Men would be different: And we ſee that ſo ſmall a Change or Diſtortion of their Courſe, as is produced in Drunkenneſs, makes the ſame Man act and think very differently from what he would if he was ſober. Laſtly, thoſe red or ſanguiferous Veſſels which ſome Authors aſcribe to the cortical Subſtance of the Brain, are nothing more

more than Part of thoſe belonging to the Pia Mater which were broke in the Separation.

§. 237. The external, *aſh-coloured* [1], *ſoft* [2], and moiſter Subſtance is termed the cortical Part of the Brain and Cerebellum, which every way exactly inveſts the whole Origin of the other internal, more white, dry, and compact Subſtance call'd their medullary Part: Even this latter manifeſtly appears to ariſe every way from the *former* [3], eſpecially in the Appendices, Ventricles, Crura, and Medulla *oblongata* [4]; but on the Reverſe, the internal Part of the *ſpinal* [5] Medulla appears like the cortical of the Brain, like which it is alſo ſpread with Arteries, and is encompaſſed with a white medullary Subſtance.

[1] This Part indeed appears red in phrenitic Subjects, and after the Brain has been injected; but in a healthy State it never contains any of the red Globules, but appears pellucid and a little bluiſh like Glaſs, approaching nearer the Conſiſtence of a Fluid than a Solid, ſo that it cannot be cut, even by a Razor, without ſticking to its Sides: And if you ever obſerve any Blood or ſanguiferous Veſſels herein, they muſt have been tore from the Pia Mater; for the red Blood and its Veſſels are always ſeated upon the Surface, and not within-ſide the cortical Subſtance of the Brain.

[2] So ſoft and tender as to diſſolve in an aqueous Liquor, and in the open Air almoſt wholly evaporates in a few Days.

[3] *Piccolhominus* firſt diſtinguiſhed the cortical from the medullary Part of the Brain, and obſerved

ſerved that the Medulla terminated in that Part of the former which was remoteſt from the Pia Mater, being proportionably thicker where the cortical Part is thicker, and thinneſt where it is covered with the leaſt Cortex; only in the Baſis of the Brain there is more Medulla than Cortex, becauſe the latter is here collected from the other Parts of the Cortex. The Medulla alſo appears to conſiſt of Filaments or Ducts ariſing from all the Gyri or convex Ridges, from whence they converge towards a Center. But we do not obſerve any ſuch Connexion betwixt the Cortex and Medulla in the Corpus Calloſum, in the Corpora Striata, in the Thalami of the optic Nerves, nor in the Peduncles of the Brain and Cerebellum; for in thoſe the Medulla is naked and covered only with the Pia Mater without any Cortex; but then the Pia Mater does not here give any Veſſels to the Medulla, nor does it ſend down any Partitions as in the Cortex, but only ſerves as a Covering.

4 The whole Medulla of the Brain and Cerebellum is collected into four Trunks or Stalks, call'd Crura, excepting what goes to the olfactory Nerves, which do not ariſe, like the reſt, from the Medulla oblongata, but from the anterior Lobes of the Brain itſelf, for which Reaſon they were rather termed Proceſſes than Nerves by the Ancients.

5 For ſo is call'd the Medulla oblongata, after it has ſent out the ten Pair of Nerves. Nature ſeems to have choſe this Inverſion of the cortical Subſtance here, for the more commodious Diſtribution of the Nerves from the medullary Part; for if the Medullary had been included in the cortical Subſtance of this Part, the Nerves muſt have perforated the latter as they paſs out from the former. Another Reaſon was to prevent the Medulla Spinalis from being compreſſed, to the Hazard

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of Life by a Surcharge of its cortical Subſtance with Blood in violent Exerciſes and Commotions, to which it would have been liable if diſpoſed like the Brain; but under the preſent Circumſtances there is a free intermediate Space left betwixt the Medulla Spinalis and its Theca or Caſe of Vertebræ, ſufficient to preſerve it from any Preſſure, which would be follow'd with fatal Conſequences.

§. 238. But in the *Cerebellum* [1], thoſe two Subſtances (§. 237.) are ſo apparent or conſpicuous, that you may there plainly perceive the manner in which the Medulla ariſes from the Cortex, with its Proportion, Fabric and Diviſions: You will alſo conſtantly obſerve the cortical Part of the Cerebellum to be firmer than that of the Brain, and more inclined to a yellow Colour.

[1] In this Part the Medulla appears beautifully divided into many ſmall Branches, like a Tree, among the cortical Subſtance, into which it appears plainly to be continued.

§. 239. Since therefore a very large Portion of the *Blood* [1], computed by *Malpighi* at one Third of the Whole, is impell'd in a direct and ſwift Courſe to the cortical Part of the Brain at each Syſtole of the Heart, it will thence receive a Motion of Dilatation and Conſtriction, though but *ſmall* [2], ſo long as its arterial Veſſels are thus fill'd with Blood: But as we are aſſured there are Arteries here, we know too that there muſt be ſmall *Veins*:

every

every where at the Termination of thoſe Arteries, though they are not viſible, through their Smallneſs and the Thinneſs of the Membranes; there muſt be alſo ſome ſecretory Canals, ariſing every where from the ſmalleſt or laſt Series of Arteries in this Gland, in which there muſt be alſo correſponding Emiſſaries or excretory Ducts, though neither can be diſtinctly ſeen.

[1] That we may the better credit the Computation of this great Man, we ought firſt to examine the Diameter of the carotid and vertebral Arteries, and then compare the ſame with the Diameter of the Subclavians and deſcending Aorta; and if we find they are not quite ſo large as to receive one third Part of the Blood, we muſt make ſome Allowance for their Vicinity to the Heart, and the Straitneſs of their Courſe to the Brain (§. 231 and *ſeq.*). And they cannot receive much leſs Blood than what is computed by *Malphigi*, if we conſider the vaſt Bulk or Quantity of the human Brain, weighing four or five Pounds, or thrice as much as that of an Ox; and conſidering too that it is compoſed of mere Veſſels without any Fat or thick cellular Membrane, with which moſt of the other Viſcera are loaded; from whence it is that the Brain never ſhrinks or waſtes like the other Parts of the Body in Conſumptions. Add to this, that the vaſcular Compages of the Brain is not ſubject to the Preſſure of any Muſcles, like the other Viſcera; nor are its Trunks of its Veſſels liable to be compreſſed by the Action of any Muſcles.

[2] Dr. *Ridley* (Phil. Tranſ. N° 287.) having removed the Top of the Cranium in a living Dog, and

and cut open the Dura Mater, perceived that the Brain itſelf had an alternate Subſultus or vibratory Motion correſponding to that of the Heart; but it muſt be obſerved, that this Subſultus is occaſioned only when the reſiſting Bones of the Cranium are removed: For while the Cranium is entire, as it cloſely inveſts the Encephalon, and is quite fill'd therewith, this latter can have no Diaſtole or vibratory Motion without removing the Sides of the Cranium, which cannot be dilated by the Force of the Heart and Arteries. Nor will the Brain and Cerebellum have any Syſtole or Contraction, ſince their Arteries have no ſtrong muſcular Coat to contract them; whence it follows, that the Veſſels of the Encephalon will remain nearly equably and continually diſtended. We may however conclude the Brain has ſometimes ſuch a Motion in a ſmall Degree, from the Obſervation of *Malpighi*, who, upon awaking out of his Sleep, had a Senſe of Light flaſhing in his Eyes when the Pulſe dilated, and an Eclipſe or Darkneſs when the Arteries contracted, which was alſo attended with a Senſation like a tremulous Motion in the Brain. But ſuch a Senſe of a vibratory Motion in the Brain can be only perceived in a Morning, when the Senſes are the quickeſt, and the Senſorium the ſtrongeſt; agreeable to which Mr. *Boyle* obſerves, that a blind Muſician had ſuch an exquiſite Feeling in the Papillæ of his Fingers Ends that he could diſtinguiſh the Colour of Objects merely by that Senſe, which he enjoyed in the greateſt Perfection betimes in a Morning; from whence it diminiſhed, till by Noon he could feel no better that other Men; concerning the Truth of which Mr. *Boyle* was ſatisfied with his own Eyes at the Expence of a long Journey. Therefore the Arteries of the Pia Mater ſeem to propel their Blood forwards in a quiet and even

Stream,

Stream, which though not equally swift, is yet so smooth and equable in a healthy State, as not to agitate the Sensorium nor disturb the Faculties.

[3] *Drelincourt* affirms, that the Pia Mater only is furnished with sanguiferous Veins, and that the Cortex of the Brain has none; which Notion I take to be just, being persuaded that the Arteries of the Pia Mater, under the Tunica Arachnoides, are divided into exceeding small Branches, which being reflected back in an opposite Course, enlarge and form the sanguiferous Veins of the Pia Mater; being those Veins through which the Injections transuded into the Sinus's of the Dura Mater at §. 234. N° 2. But the Reason why the ceraceous Injection in that Experiment passes into the Sinus's without its Colour or Pigment, and in little broken Threads distinct from each other, may be understood from the Smallness of the Anastomoses betwixt the Arteries and Veins, which kept back the gross and ponderous Parts of the Pigment or Cinnabar, and the finer Part of the Injection passing on into the diverging Veins with a diminished Velocity, must retain the Shape or Form of the small cylindrical Anastomoses, or appear like broken Threads.

Of the different Structure of the Glands.

§. 240. THE exceeding Minuteness of these Vessels in the Brain and Cerebellum, concealing their Fabric from our In-

Inſpection, has occaſioned Reaſon, though unaſſiſted with its proper Evidence, to attempt at ſupplying the Defect of Senſe by Analogy; whence various Opinions, of which the moſt received was that of *Malpighi*, ſuppoſing the Fabric of this Viſcus to be glandular, till the contrary was aſſerted by the celebrated *Ruyſch*, who has excell'd all Anatomiſts in the Art of demonſtrating and preſerving the ſmalleſt arterial Veſſels in the Body. Therefore, before we can judge of the Merits of either Opinion, we muſt firſt conſider the Bodies we call Glands, according to the Diſcoveries made of them by *Sylvius*, *Steno*, *Wharton*, *de Graaf*, *Malpighi*, *Bellini*, *Borelli*, *Pyerus*, *Nuke*, and *Ruyſch*, who have beſt treated on the Subject.

§. 241. Of theſe *Glands* [1], ſome of them are *ſimple* [2], and others compound, or an Aſſemblage of ſimple ones inveſted with one common Membrane or Integument. The ſimple Glands ſeparate their Juice from the Arteries, and convey it by their lymphatic Ducts, either into the Chyle, or the venal Blood, or elſe exhale it on the Surface of the Skin externally, or of the *Membranes* [3] internally, throughout the whole Body: But the compound Glands diſcharge their Juice, ſeparated in every ſimple one, by a ſmall Duct continued from each, into one large Canal or common Emiſſary, which either opens into ſome ample Cavity, as of the Mouth and Inteſtines, or elſe diſcharge themſelves out of the

the Body, for various Uſes, and are, from their Appearance, often termed conglobate, and conglomerate.

[1] The outward Appearance of the ſeveral Glands is ſo very different, that it is next to an Impoſſibility to frame a Definition adequate to all the Variety of them: If we define them, with *Pyerus*, to be ſecretory Organs, from their Office, that indeed agrees with all of them; but then are there not more ſecretory Organs than Glands, as the Lacteals, Vaſa Exhalantia, *&c.* ?

[2] This Name is proper to a Kind of Cells (*Folliculi vel Cryptæ*) formed each of a ſingle Membrane convoluted ſo as to include a hollow Space or Cavity, on the Convexity of which the ſmall Arteries are diſpoſed, and diſtil Part of their Contents by open Orifices into the ſaid Cavity; from whence the ſecerned Juice is diſcharged by a ſmall Tube call'd its excretory Duct, after it has been ſecreted, retained, and altered in its Follicle or Crypta. Of this Kind are the ſimple, mucous, and ſebaceous Glandulæ in various Parts of the alimentary Tube and in the Skin; and ſometimes ſeveral of theſe unite their excretory Ducts, as may be obſerved in ſome Parts of the Fauces, Inteſtines, Urethra, *&c.* Theſe have been termed conglobate by *Malpighi*, though other Anatomiſts generally give that Name to the lenticular Glands in the Meſentery, Groins, Arm-pits, Face, and Neck, *&c.*

[3] If a Portion of the Skin or Pericardium be compreſſed betwixt the Fingers, you will perceive Pores or Orifices from whence a ſoft or fluid Matter iſſues, more fluid from the latter than the former.

§. 242. The ſimple or ſmaller Glands (miliary, lenticular, multiform, *&c.*) are compoſed (1.) of a thin, uniform, external Membrane, and of another adhering cloſely to the former internally. The *firſt* [1] of theſe, conſiſting of circular and elaſtic Fibres, every way inveſts, preſſes, contracts, and empties the Gland, which conſiſts chiefly of a Contexture of ſmall Veſſels paſſing into and out of the ſaid Membrane: But the latter Integument of the Gland, being *thicker* [2] and more compact than the firſt, detaches its Fibres in all Directions among the ſmall Veſſels, rendering their Contexture very intricate, and has much the ſame Uſes with the firſt. (2.) They receive *Arteries* [3] whoſe Branches are diſpoſed and ſecured in a certain Order by the preceding Membranes, which ſo accurately retain and diſtribute the Arteriolæ to every minute Part of the Gland, that upon injecting them with Wax or Mercury, the ſmall Arteries become thereby ſo much diſtended, and the other ſmaller Veſſels ſo much compreſſed, as ſeemingly to prove the *falſe Notion* [4] of their whole Fabric being only arterious. (3.) They are alſo compoſed of *Veins* [5] diſpoſed and ſecured like the Arteries. (4.) They receive a great many *Nerves* [6], more, in Proportion to their Bulk, than any other Part of the Body; and which are diſtributed ſo minutely throughout the whole Body of the Gland that they ſeem to occupy every individual Point. Laſtly,

ly, (5.) they are alſo furniſhed with adductorp and reductory *Lymphatics* [7].

[1] This Integument conſiſts almoſt intirely of ſmall Arteries and Veins, which in a healthy State are not viſible, but appear large in Tumors and Cancers of the Glands, as if they were diſtended by Injection. 'Tis not eaſy to diſtinguiſh this Membrane from the next in ſound Glands without boiling, which ſhrinks and elevates the firſt Integument, betwixt which and the next you will perceive the ſmall Arteries and Veins diſtributed to the Body of the Gland, as they are generally diſtributed betwixt the Duplicatures of the Membranes in other Parts. The very accurate *Morgagni* has alſo obſerved, that the Fat or cellular Membrane is interpoſed betwixt theſe two Integuments of the Glands.

[2] This Tunic is found ſo robuſt and firm in the Glands of the Meſentery that the Knife can ſcarce enter it; and the Tunica Vaginalis of the Teſticles *Malpighi* has ſometimes found half as thick as ones Finger. This Integument confines the tubular Compages of the Gland, which breaks out and unravels when this reſiſting Membrane is in any Part deſtroyed: And when a Cancer has eroded the external Tunic of a Gland, a frightful Tumor always ſprouts from the Ulcer, from the degenerating of this Part, as in Cancers of the Breaſts.

[3] Theſe Arteries are ſo numerous in the ſmall Glands of the Meſentery, that, after Infection, the whole Subſtance of the Gland ſeems to be compoſed of Arteries, which depoſit their external Tunicks to each Gland before they enter its Subſtance, as manifeſtly appears in the ſmaller Glands of the Meſentery, and in the Kidneys.

4 *Ruyſch* having perfectly injected the Arteries and Veins of ſome Glands, afterwards macerated them in Water, and by ſhaking, unravell'd or ſeparated them into little Bunches, like Wool, every where fill'd, without perceiving any Follicles or Cells among them. But his ceraceous Injection was forced only into the ſanguiferous Arteries and Veins, which are the largeſt in the Body, ſo that the ſmaller and thinner Veſſels interpoſed betwixt them were thus compreſſed and obſcured, and afterwards diſſolved; for all Parts of the Body diſſolve in Water, if they have no Support to hold them together internally; (upon which Principle the whole Maſs of fleſhy Parts diſſolve in Water from the Bones, ſo as to leave what we call natural Skeletons, connected together by their Ligaments without the Aſſiſtance of Wires, of which ſort we have one prepared and given to our anatomical Theatre of *Leyden*, by *Vander Wiel*) and therefore we may ſafely affirm, that by this Method of preparing the Glands, their minuteſt Veſſels and thin membranous Folliculi or Cells were diſſolved and waſhed away in the Water.

5 After *Ruyſch* had fill'd only the Veins of the meſenteric Glands as full as poſſible with his Injection, they appeared ſo numerous and diſtended, that the Glands, which before appeared wholly arterious, ſeemed now to be nothing but a Compages of ſmall Veins; as they very well might, ſince the Veins are ſix times more capacious than the Arteries. But the red Blood, brought by the ſanguiferous Arteries, is returned again by their Veins without entring into the innermoſt Receſſes of the Gland, termed its Follicles or Cells.

6 'Tis remarkable that the conglobate Glands receive more ſmall Nerves than any other Part of the Body of the ſame Bulk; and the Glands of

of the Breaſt being ſo very nervous, are of all Parts the moſt apt to turn cancerous, when they are any way ulcerated: But that Cancers ariſe from an Irritation and Deſtruction of theſe glandular Nerves, may appear from Experience, by which we obſerve how eaſily a Wart becomes cancerous by bad Treatment, being an exuberant Fungus of the nervous Papillæ; and this ſeems to be the Reaſon why Ulcers are often ſo ſtubborn and incurable in glandular Parts. But as theſe Glands have neither any conſiderable Motion nor Senſation, their Nerves ſeem to be deſigned for ſome other Office in them, which is probably to mix and pour out ſome of their nervous Juice into the Liquor ſecerned in every Part of the Gland.

7 This has been demonſtrated by *Nucke*, that in all Parts of the Body the conglobate Glands have Lymphatics which paſs into and out of them: Even the Lacteals which are one Kind of Lymphatics, do not paſs to the Receptacle of the Chyle or the thoracic Duct before they have paſſed thro' the Glands of the Meſentery, from whence they paſs out and are diſtributed again. And as the ſanguiferous Arteries convey their red Blood in correſponding ſanguiferous Veins, ſo the pellucid Juices, which are thinner than Blood, paſs out of their lymphatic Arteries into lymphatic Veins; and we know that Water being injected by the ſpermatic Artery of the Teſticle, will paſs into and fill its Lymphatics, as it alſo will diſtend the Lymphatics upon being injected into the Arteries of other Parts.

§. 243. We muſt alſo obſerve, that theſe Arteries of the Glands are conical and elaſtic Canals, variouſly inflected, ramified, and

convoluted, till at their Extremities they become *cylindrical* [1], and change into Veins without any farther Ramifications; but then before the ſmall Arteries are thus changed into Veins, they communicate with each other by an infinite Number of *Anaſtomoſes* [2], their lateral Branches are ſent off in different Angles, and are very differently *diſpoſed* [3] in different Glands.

[1] Every Artery gradually diminiſhes its Diameter as it ſends out more lateral Branches, contracting itſelf towards an Apex like a Cone; but when it has done ramifying, there is then no Neceſſity for it to converge, but it continues its Courſe cylindrically, as we ſee by the Microſcope, in the Fins and Membranes of Fiſh and Frogs. Such a cylindric or evaneſcent Artery either continues in a reflected Courſe to become a Vein, or elſe diſcharges its contained Liquor by a patulent Orifice externally on the Surface of the neareſt Membrane; and as the Arteries thus terminate cylindrically, ſo the Veins begin or riſe in the ſame manner, and by uniting themſelves gradually acquire a larger Drameter like a Creſcent or inverſed Cone.

[2] No Affection of the Arteries has been more accurately conſidered by *Bellini* than this of their inoſculating with each other by Anaſtomoſes; from whence he demonſtrates that the Particles of the Blood impinging againſt their Angles will be divided and broke, like as a Drop of Water falling from ſome Height on an Obſtacle flies aſunder into many ſmaller Drops. As a great many of theſe angular Diviſions of an Artery may be retained in a very ſmall Compaſs or Point, it follows that the Blood may be divided into above a thouſand leſſer

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Particles merely in one arterial Spot or Bunch thus formed, than it would by paſſing on in the ſame Veſſel continued at length. Thus it is, that the Parts of the Blood are prepared for Secretion in the Glands, and divided to enter the ſecerning Orifices; and from the frequent Incurſions, its Parts will alſo acquire a rotatory Motion, like the Blood in the vaſcular Plexus of the Lungs, §. 200. 'Tis alſo by theſe Anaſtomoſes, that when Particles of the Blood cannot go on freely, becauſe of ſome Obſtacle or Obſtruction, they return back in the ſame Artery to the firſt Inoſculation, and go on laterally another way without any Impediment. This was firſt obſerved by *Lewenhoec* in a Bat, and after him by others in Quadrupeds; and I have myſelf obſerved the ſame in Men when they have turned pale with a ſudden Fright.

[3] The elegant Figures and Preparations of *Ruyſch* ſufficiently demonſtrate that there are not two Arteries diſtributed alike throughout the whole Body; for ſome run parellel, others in Arches, ſome in Heaps or Convolutions, and others in Webs or Plexus'd; ſome are diſpoſed in Bunches like Pencil Bruſhes, *&c.*

§. 244. Therefore the arterial Blood being propell'd to the Glands ſuffers there a great Agitation, *Repulſion* [1], Compreſſion, its Parts are both preſſed laterally and againſt the Sides of each other, their Contacts are continually changing, and they are forced every way, and preſented to every individual Point of their containing *Veſſels* [2], whence a perpetual Rotation and *oppoſite* [3] Preſſure of every Particle, by which they will recede laterally and run into the Branches, ſo as to be divided or atte-

nuated, ground together, compacted, polished, mixed, *kept fluid* [4], and finally *secreted* [5].

[1] The Blood pressed into the Artery by the Force of the Heart will be repell'd and resisted by the preceding Blood, which must first be urged forward before the other can succeed; the propell'd Blood will also be repressed or re-acted on by the Sides of the Artery it dilated; whence every Particle of the Blood will be pressed in all Directions against those in contact, and will not have any single Point unresisted.

[2] The smaller the Vessels the more of the Particles of the Blood will be impell'd against their Sides. (§. 213, 215.)

[3] There is a threefold Pressure upon every Particle; (1.) from the Heart, which urges the Blood forwards; (2.) the Re-action of the Globules of the preceding Blood pressing back upon that which follows; (3.) the lateral Pressure from the Arteries acting perpendicular to their Axis, and opposite to the two former.

[4] No Part of the Body is sooner or more easily obstructed than the conglobate Glands; even among ten Persons who expire of chronical Diseases, one may safely venture to affirm that nine of them will be found to have an Obstruction in the lymphatic Glands, either of the Mesentery, Neck, Throat, or some other Parts of the Body.

[5] Of these secerned Particles there are two Kinds; some of which are of the smallest Size in the Blood, passing out of a larger into smaller Vessels; and others which will be protruded by the Arteries into some common Cavity or Receptacle.

§. 245. Now every arterial Branch arising from a Trunk is found to be *smaller* [1] than its Trunk in the larger Arteries, and therefore we may conclude it is so with smaller; whence the smallest or ultimate Branches will be also less than their ultimate Trunks: Therefore the ultimate sanguiferous Arteries will transmit the thicker Parts of the Blood into the incipient sanguiferous Veins, while their smaller Branches receive the more thin, fluid, and pellucid Parts of the Blood, less than the Diameters of their Orifices, into which they will be pressed by a considerable opposite or oblique Force.

[1] Every Artery in the human Body is larger than any Branch that it emits, as we are assured by our Senses, so long as the Eye or Microscope can trace them; and it is doubtless the same in those exceeding small Arteries whose Minuteness and Pellucidity conceal them from the Eye, both naked or armed. But the Particles of the contained Fluid will be always in Proportion to the Diameter of their Canals; so that if a small Artery admitting only single red Globules is ramified, all its Branches will be less than those Globules, which they therefore will not receive; but they will admit those Parts of the Blood which are less than the red Globules, or which are proportionable to their Diameters, while the larger red Particles will pass on into the red or sanguiferous Vein. But the next lesser Parts of the Blood to the red Globules are the yellow serous ones (*per* §. 226.) and therefore the lateral Branches of the smallest sanguiferous Arteries

teries will be fill'd with ſerous Globules, and conſtitute a ſecond Order of Veſſels, *viz*, ſerous ones. That there are ſuch ſerous Veſſels is proved by the Microſcope, Injections, and to the naked Eye in an Opthalmia, where the Cruor is forced into the ſerous Veſſels of the Sclerotica. But theſe ſerous Arteries again dividing into ſmaller Branches like the ſanguiferous, will at laſt ſend out Branches of leſs Diameters than their yellow ſerous Globules, and theſe Branches will therefore be fill'd with the lymphatic Globules, which are the next leſs in Size to the yellow ſerous ones, and conſtitute a Set of Arteries of the third Order, termed lymphatic Arteries, ſuch as furniſh the aqueous Humours of the Eyes, which Humours are abſorbed or returned again to the Blood by ſerous or lymphatic Veins. Hence then, the ſanguiferous Arteries will carry all the Parts of the Blood, the ſerous Arteries will convey all but the red Globules, and the Lymphatics all but the red and yellow Globules, *&c.* and thus probably is the Succeſſion of Veſſels and Humours continued, till the ultimate or laſt Series of the ſmalleſt Veſſels convey only the moſt ſubtile Juices in the Body. We are ſufficiently convinced that there are Humours much more ſubtile than the Lymph, ſuch as the exhaling Vapours which do not become viſible unleſs condenſed by the Cold upon a Glaſs, *&c.* to which we may add the natural Sweat or perſpirable Matter which conſtantly exhales from the Body, and will obſcure a Looking-Glaſs held at ſome Diſtance, but quickly evaporates again from the Glaſs without leaving any Spot or Reſiduum; whereas the Sweat that is forced or ariſes by Exerciſe, *&c.* is ſo viſcid that it can ſcarcely be wiped off from the Glaſs, and leaves permanent yellow Spots behind it. Since therefore we are thus convinced that there

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are Liquors in the Body more ſubtile than the Lymph, we may reſt equally ſatisfied that there are alſo ſmaller Arteries which convey them, and which ariſe from the lymphatic Arteries in the ſame manner as they ariſe from the ſerous, and the ſerous from the ſanguiferous.

§. 246. But the more ſubtile Juice which thus paſſes from the ſanguiferous into the ſmaller Veſſels is no longer Blood but a *different* [1] Humour, turning either to *Sweat* [2], the Matter of the *Pores* [3], *Perſpiration* [4], *Tears* [5], *Ear-wax* [6], a *ſebaceous Matter* [7] betwixt Fat and Wax, *Mucus* [8], Saliva, *Sputum* [9], *Liniment* [10] or Mucilage, Lymph, Serum, *Bile* [11], *Semen* [12], *Oil* [13], *Milk* [14], *Fat* [15], &c.[16] whence theſe ultimate Branches are no longer call'd Arteries, but are denominated from their reſpective Juices, notwithſtanding they retain the Properties or Affections of Arteries, dividing into leſſer Branches, and uniting with correſponding Veins: Hence the Arteries and Veins are not only ſanguiferous but alſo *ſerous* [17], lacteal, lymphatic, carrying Oil, Water, Spirits, *&c.* nor can we tell where this Progreſſion, or Diviſion of the Veſſels into leſſer Series, *terminates* [18]; but we are from hence at leaſt acquainted with the Origin, Progreſs, Termination, and Office of the lymphatic Veſſels; and that there are not only *Veins* [19] ſo call'd, furniſhed with Valves, and conſpicuous to the naked Eye, but alſo Arteries of that Name, deſtitute of Valves, and render'd inviſible by their Minuteneſs and Pellucidity,

lucidity, as we are assured from the *Ruyschian* Art of injecting.

[1] Different from the Blood at its very first Secretion therefrom, and differing from its own first Sate by stagnating and exhaling its more subtile Particles.

[2] This Humour is of three Kinds, either (1.) from the glandular Follicles of the Skin, which is oily; (2.) from the exhaling Arteries, without Violence, which is thin and aqueous; and (3.) from the same Vessels forcibly distended, which is thick and serous, *per* §. 424. Sometimes we sweat out a mere Oil through the Pores of our Skin; and after violent Exercise our Linen is stiff, and stained yellow by the Serum, which has been sometimes follow'd with Blood. Dr. *Sydenham* observes in the Plague, that a slight Sweat proves of no Service; but that a clammy Sweat, holding for four and twenty Hours, expells all the Contagion. In pulmonary Consumptions we also frequently meet with clammy Sweats, which very much resemble the Serum of the Blood.

[3] I myself seem to have been the Person who first remarked this oily Matter of the Pores. 'Tis naturally a thin oily Liquor, flowing from simple Glands or Cryptæ under the Skin, thro' the Pores of the Cuticle, which are large enough to admit the Point of a small Needle without making any Wound. It serves to keep the Skin soft and smooth, and appears like an oily Dew upon a Looking-glass, as *Lewenhoec* observes. With this oily and watery Liniment a healthy Man's Face is smeered all over in a Morning when he wakes. When this oily Liniment is totally absterged from the Skin, as in the Hands of a Washer-woman, it cannot then feel the softest Body without Uneasi-

ness.

neſs. When this has been preternaturally condenſed and inſpiſſated, it is often expreſſed from the cutaneous Pores under the Form and falſe Denomination of Vermicles; and after it has been obſtructed and retained by the Cold, it occaſions an itching with Puſtules, if not diſſolved and diſcharged by Heat. *Ruyſch* chuſes to call the Follicles of the Matter in the Skin rather by the Name of Cryptæ than Glands; and has found that his ceraceous Injection tranſudes into them from the cutaneous Veſſels. 'Tis a thin Liquor at its firſt Secretion, but after ſtanding a Week or a Fortnight in the Pores and Cryptæ it becomes inſpiſſated like a ſoft Wax or Paſte in Form of a little Maggot; and from this Spring ariſes many cutaneous Diſorders.

4 The ſubtile Fumes or Vapours of *Sanctorius* which exhale from the inviſible Pores of the Skin, and which being obſtructed by the Cold, elevate the Cuticle into little Tubercles like the Skin of a Gooſe; the ſame being condenſed on the Sides of a cold Glaſs turn to a brackiſh and limpid Water without any Oil; and the Vapours of this ſort, which are condenſed on the Sides of a Looking-glaſs in the Winter-time, totally evaporate without leaving any Spot or Reſiduum. Beſides theſe, there are other perſpirable Vapours exhaled internally in the Mouth, Fauces Gula, Stomach, Inteſtines, Bladder, Thorax, Abdomen, Meninges of the Brain, in which is conſtantly an aqueous Moiſture, very different from the Serum and Lymph, and in ſuch a Quantity as to be viſible, whereas the external perſpirable Matter hardly runs into a ſenſible Moiſture. *Vid.* §. 81.

5 A Humour altogether ſingular, brackiſh, and much more ſaline than the Saliva; being intermix'd with the ſebaceous Paſte from the Glands of

Mei-

Meibomius, it forms a third Liquor, which concretes into Scales or Lamellæ by Heat, and by an Evaporation of its more fluid Parts frequently acquires a ſtony Conſiſtence, and hardens into a real Stone; which is a manifeſt Sign how much the Humours may be changed from their natural State in which they were ſecreted. This Humour is ſepatated in the Glandula Innominata of *Galen*, and convey'd to the Eye by the Ducts of *Meibomius*, to keep its Tunics moiſt, bright, and ſlippery.

6 This is ſecerned in a fluid State like Oil of Almonds, and ſerves to lubricate the very ſenſible Membranes of the Tympanum and Meatus Auditorius; but by Contact with the Air it becomes thicker, bitterer, and of a yellow Colour; as all oily Subſtances do by Heat and Standing, not excepting Cream itſelf. A Humour that very much reſembles this is ſeparated in the Follicles of the Gall-bladder.

7 Which is now call'd, almoſt by univerſal Conſent of Anatomiſts, the ſebaceous Matter: It is thicker than the oily Matter of the other Pores, and may be eaſily preſſed out of its Cells in the Skin behind the Ears, upon the Noſe, about the Nipples, Arm-pits, Nates, Pudenda, and ſuch other Parts of the Skin, whoſe greater Attrition requires ſuch a Liniment.

8 The Mucus becoming inſpiſſated by ſtanding and exhaling its more aqueous Parts, appears thicker than the Blood itſelf, but in its firſt Secretion it is as fluid as the Tears: It defends the membranous Expanſions of the olfactory Nerves within the Noſe from being injured by any acrid Particles drawn in with the Air, keeping them moiſt and fit for Senſation.

9 Which is of three Kinds; (1.) the Saliva, very fluid and uſeful in Digeſtion (§. 68.) (2.) the

the thick Sordes of the Uvula Fauces and Parts adjacent, which are indeed thin and watery at first, but become very tough and vitrious in one Night's time, by the Air; (3.) the Mucus or Phlegm from the Cryptæ of the Larynx and Trachea, by which the very sensible Membranes of those Parts are defended from the Air and its Contents *(per* §. 195.)

10 An insipid Mucilage resembling the White of an Egg, like which it hardens with Acids and Alcohol; separated in the Glands of the Joints and Capsules of the Tendons, observed by *Havers* and *Douglas*; and serving to abate the Friction of the Cartilages on the Heads of the Bones in each Joint.

11 Even this is vastly more fluid at its first Secretion in the Liver, than when it appears in common Ducts, where it mixes with the Cystic Bile. §. 88.

12 Every Body has a kind of Semen for the Production of its Species; I cannot, for my own Part, except even Gold and Stones. The Seeds of Vegetables apparently contain the Body and Fabric of the Plant; and though the Semen Masculinum is fluid, it may even under that Form contain an organised Structure, though invisible.

13 This Oil is frequently observed circulating with the Blood in its Vessels, and is secerned throughout the whole Texture of the Bones, insinuating betwixt their Lamellæ, and rendring them smooth and pliable; and particularly it is deposited in the very fine cellular Membrane within the Cavities of the Bones where it acquires the Name of Medulla.

14 Which circulates along with the Blood, and is frequently discharged with it by Phlebotomy.

This

15 This is ſecerned and depoſited in the Cavities of the cellular Membrane, which inveſts all the Muſcles and every individual Fibre of them; being originally fluid and ſoft, it by degrees thickens, and only by ſtanding in the Air becomes a hard Fat or Sewet.

16 For beſides thoſe Humours which come under the Cognisance of our Senſes, there are many much more ſubtile, whoſe Nature our Organs are not acute enough to detect and follow.

17 The largeſt of the ſmaller Arteries are ſanguiferous, which before they open into their correſponding ſanguiferous Veins, ſend off leſſer Arteries from their Sides, which receive the yellow Serum (*per* §. 245.). In the ſame manner the ſerous Arteries ſend out laterally ſome ſmaller lymphatic ones before they become Veins; and thoſe lymphatic Arteries will detach a third Series ſtill leſs, and ſo on with the ſeveral ſmaller Series, till they terminate in the ultimate or very ſmalleſt Series of Veſſels in the whole Body call'd Nerves, many of which exhale their very thin Fluid in an inſenſible Vapour through the Cuticle all over the Body.

18 No Mathematician will aſſert that Matter is not infinitely diviſible; at leaſt it cannot be prov'd abſurd: Conſider what *Lewenhoec* affirm of the Semen Aſelli (or the Inſect call'd a Cheſlop) which he makes equal in Diameter to a Sphere, the 216,oooth Part of the Thickneſs of a Hair. But Mathematicians demonſtrate, that the ſmalleſt Particle of Matter may have as many Diviſions as the largeſt; the ſmalleſt Spherule in the Univerſe has its Hemiſpheres, North and South Poles and Equator: Whence *F. Malebranch* infers, that the whole Syſtem of the World, as large as it extends, may be compriſed in a ſingle Point.

The

[19] The lymphatic Veſſels, or Veins of the ſecond Order, all diſcharge themſelves into a common Trunk or Cava, the thoracic Duct (§. 129.) which receives the more ſubtile Juices of all the reductory Veſſels, and returns them into the venal Blood; except thoſe Lymphatics which open immediately into the ſanguiferous Veins. But 'tis reaſonable to think that theſe lymphatic Veins are formed not all at once immediately, but by the Union of the ſeveral ſmaller Orders into others larger, which at length form conſiderable Branches, all opening into the common Trunk of the lymphatic Cava, the thoracic Duct; and therefore the Lymphatics return all the thinner Juices into the thicker venal Blood; both Chyle, Lymph, Serum, Vapours, *&c.*

§. 247. But then ſome of the Branches of the forementioned ſmaller Arteries (§ 245. and 246.) being no farther ramified, but continued ſtrait into the very thin Membrane, which conſtitutes the glandular *Follicles* [1], do at laſt open themſelves and diſcharge their Humours into the common Cavity of thoſe Follicles or Cells formed by the ſaid Membrane, in which the Humour is therefore collected, retained, and formed into *glandular Lymph* [2].

[1] The Circles of the lateral arterial Branches open into the Cells or Cavities of the lymphatic Glands, into which they depoſit their contained Humours; and if you preſs ſuch an arterial Opening or moſt ſimple Gland, there comes out firſt a ſoft Subſtance like Paſte, ſhaped like a Vermicle, and upon a ſtronger Preſſure there follows a Drop of a limpid Water. *Peyerus* having cut open and

cleanſed a Glandule, obſerved, by the Help of a Magnifier, that the whole Circumference of the follicular Membrane, was beſet with ſmall lympid Drops ſweating out. But you will obſerve this glandular Fabric in no Part more apparently than in the Kidneys, in which the arterial Extremities terminate in rectilinear Tubes, many of which conjoin into the Papillæ of *Euſtachius*, which receive the Urine from the Arteries, and depoſit the ſame into the common Cavity of the Pelvis, in which that Excrement is collected and retained. Such ſimple Glands, or ſecretory Tubes and Cells, continued to the Arteries, have been diſcover'd in a great many Parts of the Body by *Ruyſch*, who having happily injected the Skin, found even in that, after removing the Cuticle, a Set of Cavities or Cells fill'd the Injection in the Form of little Worms.

2 Here we meet with a Subject much controverted betwixt *Ruyſch* and *Malpighi*, viz. whether all the Lymph paſſes from the ſecretory Veſſels immediately, or whether it is firſt retained or collected in ſome Cavities of the Glands, and from thence diſcharged by the emiſſary Tube, which we call an excretory Duct. It may be ſaid for *Malpighi*, that the Glands ſwell in many Diſorders from an Obſtruction of their excretory Ducts, while the arterial Juices having a free Ingreſs, diſtend the glandular Cells into Hydatids, or little round Veſicles fill'd with the accumulated Lymph. To this *Bellini* adds, that intermediate Follicles receiving the ſecerned Juices, are evident in the Fat or cellular Membrane; in the Kidney, where the Pelvis is the common Follicle or Receptacle of the Urine from the ſecretory Ducts; and laſtly in the Liver, where the Bile is received by the Ducts, and convey'd to the Veſicula Fellis. *Ruyſch* on the other hand

hand oppoſes the Arguments of his Adverſaries by Preparations, in which he thinks it very apparent, that his ceraceous Injection paſſes directly from the Artery into the excretory Duct, without entring into any intermediate Cells or Follicles in its way: For example, in the Kidneys you may eaſily trace the Injection from the ſanguiferous Arteries into their excretory Duct the Ureter. But we may again anſwer that his Injection fills only the larger Veſſels, compreſſing the ſmaller, and therefore ſhews us the Fabric of the Glands and Viſcera but in Part.

§. 248. It is alſo probable that the Nerves of the Glands, dividing and opening into 'em like their Veſſels, diſcharge and mix their ſubtile Juice with the contained Lymph (§. 247) which by this Means acquires, in ſome meaſure, the Nature of the nervous Juice.

§. 249. But there are ſome of the lymphatic *Arteries* [1] (§. 246.) which diſcharge their *Lymph* [2] immediately into the valvular Veins of that Name; and this we call *vaſcular Lymph* [3], which is frequently carried by thoſe Veins to the ſaid Glands, and in a particular manner diſcharged into their Follicles or Cells, where mixing with the glandular Lymph and nervous Juice, they return all together in a mixt and ſubtiliſed State. Upon opening the Abdomen of a living Animal in Health, the Lymph flows ſwiftly towards the Receptaculum from all the abdominal Viſcera; which it alſo does even after Death, as we are aſſured from wounding the Lymphatics, which are

in this Action contracted by the Cold, ſupervening Death.

[1] 'Tis not at all ſurpriſing that theſe Arteries are not viſible; for the ſmalleſt ſanguiferous ones are not ſo without a Microſcope: But the largeſt ſerous Artery muſt be, at its Origin, ſix times ſmaller than a red Globule or its containing Artery, from whence the ſerous ones continually leſſen as they go. Add to this, that the Tunics of the ſmall ſanguiferous Arteries are much thicker than thoſe of the ſerous and lymphatics; and then they firſt convey a red opaque Fluid, and the others a pellucid or limpid Juice, whence it is no Wonder they eſcape the Sight, even armed with a Magnifier. From theſe Conditions we ſhould not be able to obſerve the lymphatic Veins, which are ſo vaſtly much larger than the Arteries, if they had not Valves.

[2] Which, together with the Blood, are the only Humours which concrete or harden; the Lymph containing all the Parts of the Blood except the red Globules.

[3] We may reaſonably ſuppoſe that the returning nervous Juice conduces much to the Compoſition of this Lymph (*per* §. 292.); for the evaneſcent Nerves terminating with the ſmalleſt lymphatic Arteries compoſe lymphatic Veins, which are the very ſmalleſt that return Lymph, and theſe Veins uniting into larger Series of nervous Veins, will at laſt conſtitute an ordinary or common lymphatic Vein, ſizable to the Number of ſmaller Veins from whence it ariſes. This vaſcular Lymph is therefore different from that of the Glands, being thicker and continually in a Circulation.

[4] This vaſcular Lymph is returned to the Glands, after it has been ſecerned and convey'd out of

of the ſmaller into the larger lymphatic Veins, having Valves, which is the Opinion of *Nucke*, and confirmed by *Malpighi* : So that the vaſcular Lymph returns to the Glands in the ſame manner as the Chyle paſſes to them from the Inteſtines, by the Lacteals of the Meſentery.

§. 250. This compound lymphatic Humour is in the next Place propell'd through thoſe ſmall reductory lymphatic Veins (§. 249.) to other Glands of the ſame Nature for the ſame Purpoſes (§. 249.) and this partly by the Contraction of their own *fibrous* [1] Membranes with the Preſſure of the *Muſcles* [2], and partly by the Pulſations of the adjacent *Arteries* [3] : From theſe laſt Glands it again Paſſes to the Receptacle at the Loins, and thence by the thoracic Duct into the ſanguiferous *Veins* [4]. And theſe ſeem to be the conglobate *Glands* [5] of the whole Body.

[1] Notwithſtanding theſe Membranes appear ſo very thin in the lymphatic Veſſels, we find they are pretty ſtrong, and exert a conſiderable contractile Force.

[2] For when the Muſcles are at reſt, the thinner Juices, and eſpecially the Lymph, go on but very ſlowly ; whence we frequently meet with Stagnations, and Obſtructions of that Humour, forming a dropſical ſwelling of the Legs, very frequent in thoſe who lead a ſedentary Life, or who ſit and ſtand much.

[3] The ſmaller ſanguiferous Arteries which run parallel to the Sides of the ſmaller lymphatic Veſſels, in the ſame manner as the large red Arteries and

Veins usually accompany each other; or as the largest of these Lymphatics, the thoracic Duct, runs by the Side of the Aorta.

[4] Either into the Subclavian Vein by the thoracic Duct, or else immediately into the jugular Veins, Emulgents, or the Cava.

[5] These Glands are of two Kinds: Some very minute, which separates the Lymph and are invisible (§. 247.); others which are large and conspicuous, like those of the Mesentery, which first receive and elaborate the Chyle (§. 242.).

§. 251. But in other Glands the secerned Juices are disposed of in a different Manner, their Follicles (§. 247.) discharging each their contained Liquor, by their Emissaries, into one *common* [1] Cavity; as in the Cells of the Bones, Sinus of the Os Frontis, Antra of the upper Jaw, Sinus's of the Os Sphenoides under the Sella Turcica, Meanders of the Os Spongiosum in the Nose, the Cavities of the Nostrils and Fauces, with the Lacunæ of the Tonsils; in all which the secerned Mucus is deposited, accumulated and changed. To these we may add the mucous Glands of the Mouth, in the back Part of the Tongue, withoutside and within the Epiglottis, the internal or sensitive Parts of the Nose, and the internal auditory Passages, in the Fauces, Larynx, Trachea, Bronchia, Oesophagus, Stomach, *Intestines* [2], &c. in all which they may be termed simple excretory Glandules.

[1] The Bones of the Forehead and upper Jaw are in the Fœtus composed of solid and compact Lamellæ,

mellæ, without any Sinus's in them; but in the new-born Infant their bony Plates diverge by degrees from each other, and leave small Caverns, of which that in the Os Frontis will contain about two or three Drams of Liquor, those of the upper Jaw, when pretty large, will hold near an Ounce of Water each, and that in the Os Sphenoides will receive a large Bean. These Sinus's are invested internally with one continued Membrane, in which the Vessels are disposed in a particular and beautiful Order, as the Injection of *Ruysch* demonstrates. But the whole internal Superficies of this Membrane is not only spread with Vessels, but also every where beset with little rough Tubercles, like small Grains of Millet-seed, which are the Cryptæ or little Cells, upon whose Convexity, over-against their emissary Ducts, the small Arteries are disposed and spent; terminating with their open Extremities inserted into the Cavity of each Follicle, like Velvet or the Down of a Peach, thro' which pendulous or villous Extrenities of the Arteriolæ, *Ruysch* has thrown his Injection even into the Cavity of the Follicle. Through these villous Ducts of the Arteries a thin and aqueous Moisture distills into each Follicle, where it is retained and inspissated, either by an Exhalation or Absorption of the more fluid Parts, or both, whereby the Remainder is digested into a thick Mucus, differing in Degrees of Consistence in different Parts; but so cohesive in a robust and healthy Body that one Drop will not fall from the other, as Water will. This Mucus draining from the small Apertures of its Follicles, lubricates and defends the very fine olfactory Nerves, which are the most naked and exposed of any, but by this Defence are secured from the Dryness of the Air, and the Acrimony of its contained Particles: But when this Secretion is in-

creaſed, and the Abſorption of its more aqueous Parts impeded by the Winter Cold, it diſtills in thin, watery, and cold Drops by the Noſe, eſpecially in old People. The ſame Structure is alſo in the Folliculi of the Fauces, and whole alimentary and aerial Tube; and in the back Part of the human Tongue they appear ſo numerous and very conſpicuous to the naked Eye, after cleanſing it, that there remains not the leaſt Room for Scruples or Doubts, nor does even *Ruyſch*, who ſo ſtrenuouſly argues for the vaſcular Fabric, refuſe to admit theſe Cryptæ.

[2] All this that has been ſaid is alſo applicable to the Cryptæ of the Inteſtines, which have the ſame Affections. When the follicular Secretion is augmented in the Noſe and Fauces, it produces Catarrhs or Defluxions of thoſe Parts; in the Larynx, Trachea, and Bronchia, it produces a pulmonary Catarrh; and, in like manner, a Defluction in the Inteſtines, *&c.* From the Noſe this Mucus is diſcharged by ſneezing or blowing, from the Fauces by ſpitting, from the Wind-pipe by coughing; and from the Stomach, a like viſcid inodorous Phlegm is diſcharged by vomiting, and from the Inteſtines in the Depoſition of their Fæces, *&c.*

§. 252. There are again other ſuch Follicles or ſimple excretory Glands, which, having the ſame Mechaniſm (§. 251.) diſcharge their contained *Humours* [1] by proper Emiſſaries, opening, not internally, but withoutſide the Skin; ſuch are thoſe of the external auditory Paſſages, the external Sides and Tip of the Noſe, the internal Entrance of the Noſtrils, in the Face and *Cheeks* [2], Neck, Armpits,

pits Shoulder-blades, round the Nipples of the Breasts, round the Navel, Hips, Nates, Anus, Perinæum, Pube and Mons Veneris in both Sexes, Scortum, Skin of the Penis, Labia Pudendi in Women, and about the Knees; to which modern Anatomists have given the Denomination of sebaceous.

[1] We before laid it down for a Rule, that every Humour is thin and limpid at its first Secretion; nor are we to except the oily Matter which Nuture has supplied to the Skin, to defend it from the Injuries of the Air and the Attrition of other Bodies. This oily Matter, originally very thin, aqueous, and fluid, by exhaling its more volatile Parts becomes inspissated, and of the Consistence of a soft Paste or Wax, call'd by *Morgagni*, and other *Italian* Anatomists, by the Name of sebaceous Matter.

[2] Inspect the brown and dirty Face of a Country-man, Sailor, *&c.* and observe with what a vast Number of large Pores the Skin is perforated; each of which has its Sphincter and subjacent Cell or Gallipot full of oily sebaceous Matter, which ought not to be esteemed a Matter coming immediately from the Arteries, since it is collected and changed in the intermediate Follicles. From these large Pores transudes (either by the Heat of the Body, of the Sun, or by external Pressure) a sort of Ointment which makes the Face shine, and upon wiping it off on a clean Cloth, or a Piece of writing Paper, it appears quite oily. By standing long in its Cells, and evaporating its more fluid Parts, it becomes so thick that you may press it out of the Pores in little round Cylinders, like Maggots, with a black Head or dirty End. Its great

great Use is to mollify the Cuticle, and dispose the subjacent Papillæ of the Skin for the Sense of Feeling; for when this Matter has been totally absterged from the Finger's Ends with Soap and Water, as in the Hands of a Washer-woman, we cannot feel even the softest Body without Uneasiness. It also serves to defend the Skin from destructive Friction; in the same manner as Sailors rub their Hands with Tar to prevent their Excoriation when they let Ropes run swiftly through them.

§. 253. Hence the Humours will be various according to the Distance of the *Artery* [1] from the Heart, its *Situation* [2] with respect to the Heart and the Trunk from whence it arises, its different *Complications* [3] and Number of Ramifications before it terminates, the different *Velocity* [4] of the Blood moving through it, the Proportion that the single *Branch* [5] bears to its Trunk, the different propelling *Forces* [6], both external and internal, which discharge the Humours, the different Time of its *standing* [7] in the common Cavity or Receptacle, and the various Passages it goes thro', from thence making new Changes, with the different Degree of Absorption or *Exhalation* [8] of the more fluid Parts from the secerned Juice; all these Causes, I say, concur to produce that vast *Variety* [9] of Humours observed in the several Parts of the Body, from that one common Mass the Blood, whose Particles are thus variously sorted, separated, and combined in a *wonderful* [10] Manner.

[1] 'Tis

[1] 'Tis easy to conceive that the Blood which is nearest the Heart will be different in the Motion and Combination of its Particles from that which is more remote, since the last will go on very slowly and retain but little of the Force which the Heart impressed on it; for to produce the Force which 2 will exert at the Distance of 3 from the Heart, will require the Force of 6 at the Distance of 9.

[2] The Angle which the mammary Artery makes with the Subclavian from whence it arises, is very different from the Angle formed by the Carotid and its Trunk: And the Secretions derived from both are equally different. The most solid, dense, and spherical Parts of the Blood will be carried in a Direction nearest to that of a right Line; while the other Particles will recede or go off laterally in various Angles, according to their different Solidities, whence will arise a great Difference in the glandular Secretions.

[3] These have been demonstrated by *Ruysch* to be not alike in any two Glands (§. 143. N° 3.): Thus the small Arteriolæ of the pituitary Membrane are strait, in the Spleen they form Penicilli or Bunches like Pencil Brushes, in the Kidneys they take a serpentine or vermicular Course, in the Lungs and elsewhere they form Plexus's or Networks, which are different in various Parts, *&c.* Hence in complicated Arteries the Blood will dilate them more, as striking more directly or perpendicularly against their Sides; but then the Blood goes on slower in such, because of the increased Friction, when the progressive Motion being diminished Attraction betwixt the Parts will then take place, and they will combine variously.

[4] The Blood's Velocity is greatest in the Heart and Lungs, and then in the Aorta near the Heart, from

from whence the Blood gradually moves ſlower as it recedes farther from the Heart. But the Blood's Fluidity is in Proportion to its Velocity; for by Reſt or a ſlow Motion it becomes thick, but by a ſwift Circulation it diſſolves, and becomes more fluid: Thence *Lewenhoec* obſerved the Blood moving much ſwifter and with an accelerated Motion in the ſmall Veſſels near the Heart at each Syſtole; but in the Capillaries of the Extremities he obſerved the Blood to move with an uniform and equable Velocity.

5 The ſmaller the Branch is, with reſpect to its Trunk, the more fluid will the Liquor be which flows into it. Some have only regarded this Principle in accounting for the Secretions; but the different Diameters of the ſecretory Orifices will not ſuffice alone.

6 The more Liquor there is excreted from any Gland, the more there is ſecerned in it, and the Reverſe; whence the Secretions will vary much according to the Cauſes which increaſe or diminiſh them. If a Perſon drinks a great deal of ſmall Beer, he ſoon after makes a great deal of aqueous Urine, and then ſome time afterwards he will void a leſs Quantity of a more yellow and fœtid Urine; therefore by only increaſing or diminiſhing the Impulſe of the Blood and nervous Juice, the ſame Glands will vary their Secretion both in Quantity and Quality. I viſit an hypochondriacal Patient who makes yellow Urine for the preſent, but upon hearing ſome diſagreeable News, a ſudden Conſtriction follows in the Kidneys, and they only ſecern a thin pellucid Water: The Blood and the Kidneys are ſtill the ſame, only the Orifices of the ſecretory Tubuli are ſo contracted by the Spaſm or convulſive Motion of the Nerve, that they will only admit the thin and aqueous Parts; the Nerves

in

in the Glands have therefore a great Influence and Concern in their Secretions. Some Glands are indeed preſſed and urged on to their Secretions by the Protruſion of the Arteries only, as the Brain, Cerebellum, and ſpinal Medulla; and others are influenced by the Preſſure of the adjacent Muſcles: In the firſt therefore the Secretion will be more ſlow and equable, but in the laſt more accelerated and unequal.

7 If the Noſe is continually blowed, the Mucus will not have Time enough allow'd it to thicken, and will therefore be thin and fluid; but if it ſtands all Night in its Receptacles, it will, by Morning, become almoſt as thick as Glew. The Bile of the Liver is thin and mild, but that which has ſtood ſome Time in the Gall-bladder is more thick and bitter. Even the Fat is a thin Oil like Water at firſt, but acquires its Conſiſtence by ſtagnating. Hence, how eaſily may we account for the Viſcidity of many Secretions from a Principle that has eſcaped moſt who have treated on the Subject?

8 The Semen in the Teſticle is, at its firſt Secretion, as thin as the Tears, but in the Vas Deferens it becomes inſpiſſated into a Gluten.

9 It cannot be properly ſaid that thoſe Humours are, as ſuch, in the Blood, becauſe they are thence prepared and ſeparated by the Glands; for the Blood contains no acrid Bile, viſcid Mucus, bitter Ear-wax, nor ſeminal Animalcula, *&c.* but yet it contains the Matter out of which thoſe, and all the other Humours of the Body, are form'd; which common Matter of the Juices is convey'd from the Heart by the Arteries to the ſecretory Organs, but does not arrive there in the State we afterwards obſerve when it has paſſed the Secretion. Nobody will allow me to give the Name of Ale

to

to Barley, becauſe ſuch a fermented Liquor is prepared from it. The Liquor carried to the Teſticles for the Formation of Seed no more deſerves that Name till it has paſſed the Secretion, than a rough Lump of Iron deſerves to be called a Sword or Dagger. The ſeminal Humour is ſecerned thin and lympid from pellucid Arteries which do not admit the Cruor, from whence it is tranſmitted by exceeding minute Tubuli into the Duct of *Higmore*, and paſſing through the Curls of the Epididymis, and Convolutions of the Vas Deferens, it at length arrives into the common Receptacle of the ſeminal Veſicles, in a State very viſcid and different from what it was originally.

[10] 'Tis more than a little ſurpriſing, even to a wiſe Man, that the Blood ſhould afford ſuch a Variety of Juices, and that ſo conſiſtent a Maſs ſhould, by the Efficacy of repeated Circulations, yeild ſo thin a Fluid as the perſpirable Matter of *Sanctorius*, which, after being condenſed on a Glaſs, exhales without the leaſt Appearance of any Fæces or Reſiduum. Nor ought we to imagine the Humours ſo very different from each other as they might at firſt appear to us; for Chemiſtry teaches us that they afford all the ſame Principles; but they differ in Conſiſtence and the various Proportion and Combination of their Parts.

§. 254. Theſe Cauſes (§. 253.) varying in different Glands, and acting *ſeparately* [1] or conjunctly, are demonſtrated either to our Senſes from the Thing itſelf and the Structure of the Parts, or are from thence deduced with the utmoſt Evidence that the infallible Laws of Mechanics will admit, aſſiſted with a Knowledge of the Nature of each Humour, which

may

may be easily obtained by every one, since they have them in Possession: We are therefore from hence enabled to understand the vast Number and Variety of the Secretions and Excretions throughout the Body.

[1] Scarce any one of these Conditions is the same in two secretory Organs, much less is there the same Agreement of several of them in different Glands, if those Organs are compared together. But if those ten different Conditions be variously combined, without any regard to those we know nothing of, they will in Reality produce a thousand Juices all very different from each other. We know, by the Rule of Combination, which directs to multiply the Product of the lesser Term by the next greater, that ten Terms may be combined 362,880 different ways, as all the Words in a Language are composed of the Letters in the Alphabet; for the Combinations of 2 will be $2 \times 3 = 6 \times 4 = 24$, &c,

§. 255. We have therfore not the least Occasion to imagine set *Pores* [1], of various but immutable Sizes and Figures, to account for the Phœnomena of Secretions (§. 254.): It is even repugnant to the Laws of Nature for any such to be in the human Body, or if there were, for them to act in that manner.

[1] This has been a very ancient Method of explaining the different Secretions; for *Celsus* describes the Hypotheses of *Asclepias* and *Erasistratus*, explaining them all by invisible Pores, and the Figures of the Particles. The same Method of accounting for the Secretions has been also lately revived

vived by *Carteſius*, and this even with the Conſent of ſeveral eminent and ingenious Phyſicians, as *Borelli Gulielmini*, *&c.* They compared the ſecretory Organs to Sieves, furniſhed with immutable Pores of various Sizes and Figures, adapted to the various Particles: Thus the different Glands were reputed to be Sives with Pores, that when the Blood offered itſelf to them, it only parted with ſuch Particles as were adequate in Size and Shape to each Strainer, whence a Variety of Humours from the ſame Blood. But this is far from giving a juſt Solution of the Problem, why different Juices are ſecerned in different Parts of the Body of a determinate Nature: For (1.) we demonſtrate that all the Canals of the human Body are round (§. 212.) ſince neither Reaſon or the Microſcope could ever diſcover Canals but what was circular in every Section. (2.) If a ſecretory Duct ſhould from any Cauſe acquire a Shape different from a Circle, it would eaſily change that Shape upon any ſlight Effort, ſince its Membranes are ſo ſoft and lax as eaſily to give way. The ſmalleſt ſanguiferous Arteries of the Body are indeed viſible by a good Microſcope, though the ſecretory Ducts are not, which are therefore much ſmaller than the firſt (*per* §. 245.) and conſequently more ſoft and yielding than the ſmalleſt ſanguiferous Arteries, which are themſelves ſo tender as to break or diſſolve by touching them; and when their ſmall reſiſting Coats give way to the Impulſe of the Blood, they are always thereby diſtended circularly or every way equally alike, ſince the Blood impells againſt every Point of their Sides in equal Radii from their Axes. We are alſo ſatisfied that the ſame Viſcera always ſecern the ſame Humours, even upwards of fifty Years, the ſame Bile, the ſame Urine, the ſame Milk, in the Liver, Kidneys,

neys and Breaſt; but this could not be done if the Glands change the Figure of their ſecretory Ducts, for ſuch a Change would confuſe the Secretions, and cauſe Bile to be ſeparated in the Kidneys, Urine in the Breaſts, *&c.* (3.) But even granting immutable Pores of various Figures, and Particles of the Blood of various Figures, it will not follow that ſome Pores will only receive one kind of Particles and refuſe the reſt; for whatever be the Figure of a Pore it will admit all ſorts of Particles whoſe largeſt Diameters are leſs than its own; and it would even reject its own adequate Particles if they did not preſent in a certain determinate and favourable Poſition, as *Pitcairn* demonſtrates. We would not however be underſtood to deny that the Secretions depend very much on the Fabric of the ſolid Parts; and that the different Structure of the Glands in the ſeveral Parts of the Body will occaſion different Juices to be ſeparated. If any glandular Part which ſecerns a mild and innocent Juice to be contuſed or injured by ſome external Violence, the Secretion is preſently diſorder'd, and follow'd with various morbid Symptoms, or perhaps a Cancer, diſcharging a moſt acrid and deſtructive Juice, only from the Defect or Injury of the Solids, by which the Juices extravaſate or ſtagnate, and become putrid or corroding. The Liver being obſtructed often petrefies or hardens like a Stone, and ſecerns Juices of a different Nature from healthy Bile. The Fabric of the ſecretory Organs therefore tranſmutes the ſecerned Juices, as the ſame Juice of the Earth is diverſified by different Plants into various Liquors, ſo different from each other, as the bitter Aloe or Colocynth, and the ſweet Sugar-cane, the fat Olive and the watery Gourd, the ſoure Lemon, *&c.* All which Variety of ſecerned Juices reſult from the inſcrutable

Mechaniſm of the animal Veſſels or the vegetable Tubes, the different Velocity with which they are propell'd, and the various Combination of their Particles, *&c.*

§. 256. Much leſs need we have Recourſe to any precarious *Ferments* [1] in the Glands to ſolve theſe Phænomena (§. 254.); whether you imagine thoſe Ferments to be thick and conſiſtent, or thin and fluid, and poſſeſſed of a Power to ferment, precipitate, coagulate, diſſolve, change, or aſſimulate; for nobody could ever aſſign the Cauſe, Origin, Matter, Place, Mixture, Efficacy, Proportion, Continuance and Effects or Uſes of ſuch Ferments.

[1] The chemical Writers have defined a Ferment, after *Helmont* and *Paracelſus*, to be a Subſtance which, upon Mixture with another, changes the latter into a different Nature from what it had of itſelf without the Ferment: Thus Water being mixed with a Maſs of fermentable Meal into a Paſte or Dough, ferments much ſooner and more perfectly by adding a Portion of Leven or other Dough that has been well fermented. Theſe Writers believe, and I was once myſelf of their Opinion, that no internal Change is wrought in any Body without a Ferment, in the ſame manner as no vinous Spirit can be procured from any vegetable Subſtance without a previous Fermentation. The different Secretions are, according to them, made all by ſpecific Ferments lodged in every Gland and Veſſel; which Ferments change the newly arrived Juices into their own or a different Nature; thus, for Example, in the ſeminal Veſicles,

cles, say they, is lodged a seminal Ferment, which mixing with the Particles of the Blood derived by the spermatic Vessels, changes that Blood into Semen. The Weakness of this Hypothesis is easily seen through; for every Ferment must be fluid on their own Principles, or else they could not mix with nor change the Blood into different Juices. Allowing therefore their Ferments to be fluid, they must mix with the Blood either (1.) by entering the Arteries, which they cannot, since the Blood moves in those Vessels uniformly to all Parts in a Direction that opposes the Return of any Juices: Or, (2.) they must be lodged in the Follicles of the Glands and there mix with the Juices; but then how do they perform the Secretion which is already made? Or (3.) they mix with the Blood in the Veins; but no Secretion is thence made in any Part; whence it follows that Ferments have no Existence in the Body, and that they are incapable of mixing with the Blood, and producing its Secretions.—Add to this, there is no probable Cause or Origin of any such Ferment that can be assigned by any one. If they say those Ferments are coeval and born with the Animal; consider the Smallness of their Quantity that can possibly be lodged in the very minute seminal Animalcule, or its still lesser Glands; and then consider the immense Quantity of Juices secerned in the Body for fifty Years successively, which in the Urine only will at least amount to 22,500 Pounds: You will then readily conclude that there cannot be Ferments enough lodged in the minute Stamina of the incipient Animalcule, sufficient to mix with and change the Juices for so many Years, and not be washed away. If you say the Ferments themselves are originally in the Blood, and direct its particular Juices to enter particular Parts of the Body, we then ask

what causes the Parts of one Ferment not to act in its kind on Juices in other Parts than its own, and then what becomes of the unactive Ferments in the Parts? at that Rate there will be an infinite Progression of Ferments required to govern each other.

§. 257. Of these more simple Glands before described (§. 242 to 254.), or others of the like Nature, conjoined together by communicating Ducts, and invested with one common Membrane, are formed those compound and larger Glands which we term *conglomerate* [1]. These have generally one common Emissary, into which the small excretory Duct of each simple Gland opens and discharges its Liquor, which being collected by the common Duct, is by that convey'd into some larger Cavity. *Of this kind* [2] are the lacrymal Glandula Innominata of the Eye, the Parotids, Pancreas, *&c.*

[1] If the parotid Gland be macerated some time in warm Water, and then denudated of its common Membrane, it will appear to be composed of small conglobate or round Glandules in Clusters like Grapes, in opening any one of which you will perceive it furnished with an Artery, Vein, Nerve, and excretory Duct, all constituting one of the least conglobate Glandules; whose excretory Duct unite with that of its nearest neighbouring Glandule, and so with the rest, till all their small Ducts uniting into larger Branches, form at last one large excretory Canal. But if you compare the Fabric of the Liver with this Structure of the Parotid, there

there will be found a great Uniformity in both; *i. e.* the Liver will alſo appear to conſiſt of ſimple Glands (§. 247.) formed into little Bundles, again conjoined into Bunches; as *Malpighi* has aſſerted in Oppoſition to *Ruyſch*, who by his Injections endeavours to prove that thoſe Bundles are only Penecilli, or Bunches of Veſſels like little Pencil Bruſhes, detaching ſecretory and excretory Ducts immediately from the Anaſtomoſes of their Arteries and Veins, without any intermediate Follicles or Cells. I ſay, without any regard to their different Opinions, the Liver will appear a Congeries of little Bundles like Grape Stones, united into Cluſters or Bunches by their excretory Ducts, which at laſt form the Pori Biliarii and Ductus Hepaticus. That thoſe Bundles are formed of mere ſimple Glands is apparent from a morbid Diſpoſition or Petrification of the Liver, which in ſuch a State appears to conſiſt wholly of ſpherical Bundles like Bunches of Grapes, the Cavities of which are fill'd with a hard congealed Matter, included in every diſtinct Cell. Hence it follows that the conglomerate Glands are no more than a Number of the conglobate ones uniting their emiſſary Ducts, and convoluted together in one Membrane, or that the firſt is a Repetition of the laſt.

[2] Hitherto belongs the Thymus or large Gland in Infants, ſeated in the Top of the Thorax above the Baſis of the Heart. From this Gland I was informed that a Duct aroſe, and went into the Oeſophagus towards the Stomach, in a Letter ſent me by an *Italian* Anatomiſt.

§. 258. But ſometimes the common emiſſary Duct (§. 257.) forms a ſort of arterial and inflected *Canal* [1], in which the ſecerned

Juice is digested or altered, before it is thereby convey'd, as through an Artery, into the common and larger Cavity (§. 257.); of which we have an Instance in *Higmore*'s Duct, the Epididymis, and Vas Deferens of the male Testicle, leading to the seminal Vesicles: But sometimes again, the general excretory Duct or Emissary opens immediately into the common Emunctory or *Cavity*[z].

[1] Another Instance of this kind we have in the Ureter, which conveys the Liquor secerned in the Kidney, to a second Follicle or Cell; *viz.* the urinary Bladder; which generally holding ten Ounces of that Liquor, demonstrates its Retention there, by which it will certainly be alter'd from the first State in which it was separated from the Blood. But in the Testicle this Fabric is very surprising, the emissary Canal changing its Diameter three several Times; for the Diameter of *Higmore*'s Duct is larger than that of the seminiferous Tubuli; that of the Vas Deferens is still larger than the Duct of the Epididymis; and that of the seminal Vesicles still larger than the Vas Deferens; there being also a Contraction or Narrowness interposed betwixt the Tubuli of the Testicle and Duct of the Epididymis, betwixt the Epididymis and Vas Deferens, and betwixt the Vas Deferens and seminal Vesicles; whence if by an Artery we understand a conical converging Vessel, and by a Vein one that diverges, we shall here have thrice an arterial Structure and thrice a venal, betwixt the Secretion and Excretion of the Semen.

[z] We have a particular Mechanism in the Articulations of the Bones, where the mucilaginous Glands of *Havers* are placed in some Cavity of the Cartilage,

Cartilage, and discharge their Juice into the common Cavity of the Capsule, which invests the Joint, to prevent the Cartilages from heating by Attrition and giving Pain. But then this Liquor is never lost or discharged out of the Body, since it has no excretory Duct opening externally; therefore it must be continually attenuated by the Motion of the Joint, and again returned or absorbed by its proper Ducts or Veins; but if it stagnates some time for want of Absorption, it becomes acrid and excites violent Ischiadic Pains; and such Disorders frequently arise from a sedentary or inactive Life.

§. 259. From hence therefore we are assured that the Glands separate not only Water, Lymph and thin Serum from the arterial Blood, but also very subtile, saline, oily and spirtuous Parts mixed together with them; and that all those Juices are either collected and retained, accumulated and changed in certain Cavities or Receptacles for the Purpose, or else propell'd through the smaller Vessels into the minutest Recesses of the Body, for muscular Motion and Nutrition; and that having performed those Offices, they are either returned by their corresponding *Veins* [1] to the Heart, or else exhaled out of the Body; and lastly, that the remaining thicker Part of the arterial Blood, from whence they were first separated, is sent forward into the gradually diverging Veins, where mixing with the other venal Blood and diluting Lymph, it at length

returns into the Heart again, from whence it came.

[1] *Bellini* rightly obſerves, that the Inteſtines make up one of the largeſt and moſt conſiderable Glands in the Body, ſince they are furniſhed with all the Parts of ſuch a ſecretory Organ. The firſt Receptacle of this Gland is the Stomach, into which are convey'd the Liquors of the Mouth, Fauces, Oeſophagus, and of the Stomach itſelf; from whence they paſs, after being digeſted with the Food, into the Duodenum and ſmall Inteſtines, which make the ſecond Part of this great chylificative Gland; and here they mix with the Bile, Juice of the Pancreas and Inteſtines: ſo far therefore in this Part Nature imitates the Follicle of a Gland, into which the Arteriolæ pour their Juice: But this is not all, for the Inteſtines likewiſe reſemble a Gland in their Separation or Abſorption of the Chyle, by the minute Orifices of their lacteal Veins, by which it paſſes to the Blood, while the more groſs and excrementitious Parts are rejected by the Anus. In the ſame manner we have in all other glandular Follicles both excretory Ducts and abſorbing Veins.

§. 260. For which reaſon (§. 259.) the arterial Blood is the moſt fluid or *dilute* [1] near the Heart, gradually thickening in its Progreſs till it comes to the End of the Artery, where that joins to the incipient Vein; in which Place it will be thickeſt, moſt *viſcid* [2], and apt to concrete; there it therefore requires a Veſſel not liable to *Obſtruction* [3], with an additional Mixture of *diluent* [4] Juices, that is, of the Lymph and nervous *Juice* [5] returning to the Heart, after the Performance of their Offices:

fices: But it was neceſſary for this Dilution of the Blood to be made before its Propulſion into the *pulmonary Arteries* [6]; otherwiſe it wou'd not be able to paſs through 'em and circulate again.

[1] All the Juices of the Body are ſecerned from the arterial Blood of the left Ventricle; but the Blood is the thickeſt of any of our Fluids (*per* §. 226.), and therefore all the Juices thence ſeparated muſt be thinner than the Blood itſelf, whoſe thicker and red Parts are never diſcharged out of the ſanguiferous Arteries in a healthy State, if we except the menſtrual Flux. The Blood will therefore be thicker, and leſs moveable in the Extremities of the ſanguiferous Arteries than in any other Part of the Veſſels, ſince all the Secretions of the thinner Parts are made from it before it arrives there. But the Blood is moſt fluid in the Heart, where it contains all the Sorts of Particles both ſubtile and groſs, very intimately mix'd with each other, which Mixture conduces much to Fluidity in a Liquor compoſed of diſſimilar Parts; but this will be leſs in the evaneſcent Arteries.

[2] The natural Diſpoſition of the Blood is to concrete or turn ſolid, and the Fluidity thereof is forced by Motion communicated from the Heart and Arteries; nor does it continue that fluid State any longer than its Parts are kept from cohering by that Motion with the Addition of ſome Water (§. 229.); but thoſe watery Parts ſeparate from the Blood before it reaches the Anaſtomoſes of the Arteries and Veins, and therefore the blood which there remains will be the moſt viſcid and apt to concrete.

3 Life would be continually in the higheſt Danger, if the Blood was to paſs from the evaneſcent Arteries into Veſſels reſiſting its Motion; but the Veins continually diverge, ſo that the thick Blood entering ſlowly from their Anaſtomoſes or Beginnings, meets with the leaſt Reſiſtance, which continually leſſens as the Veſſels enlarge.

4 The more fluid Parts of the Blood, which were ſecerned by the lateral Emiſſaries from the ſanguiferous Arteries, do not totally deſert the Blood or leave the Body, but are returned into the Blood again by the Veins, excepting what exhales or is thrown off by the Emunctories. And as the ſmall, red ſanguiferous Arteries in many Parts ſend off yellow ſerous ones, ſo the ſmaller ſanguiferous Veins alſo receive ſerous Veins ariſing from their Arteries, and returning the yellow Serum: And ſuch of the thinner Parts of the Blood as do not return this way, are convey'd into the reductory lymphatic Veins, moſt of which unite into one large Trunk or Cava, the thoracic Duct, by which the Lymph is poured into the venal Blood before it reaches the Heart.

5 Which having performed its Offices returns into the Blood again by the lymphatic Veins (*per* §. 292.); and to this Juice of the Nerves we may add that taken in by the inhaling Veins (§. 126. N°. 4. §. 182. N°. 5. §. 201. N°. 10. §. 295, and 421.) For as many of the ſmaller Arteries are continued directly into patulent Ducts, which exhale moiſt Vapours on the Surface of their Membranes, either in the Air externally, or into the Cavities and Interſtices of the Body internally; ſo there are alſo correſponding Veins which abſorb from the Air externally, and from the ſaid Cavities internally, by which Veins thoſe Vapours are returned into the Blood: And that the Air which every

every way invests us is replete with watery Parts, appears from the Quantity attracted thence by dry Salt of Tartar. Therefore whatever moist Vapours are contained in the Air, they will be absorbed by the inhaling Veins opening thro' the Cuticle externally; but in no Part will they absorb more than in the Lungs, because there those inhaling Vessels are so large, as to transmit the ceraceous Injection of *Ruysch*, which being forced into the pulmonary Vein, escapes by these Ways into the Vesicles and small Ramifications of the Bronchia.

6 The venal Blood returning from all Parts of the Body to the right Ventricle of the Heart, passes thence from a larger Capacity to a less, *i. e.* out of the right Ventricle into the narrow converging Arteries of the Lungs, where it wou'd stagnate, concrete, and cause a fatal Peripneumony, if it was not more fluid and dilute than in the incipient Veins; in the same manner as Spirit of Nitre being injected into the Veins of an Animal turns the Blood into Grumes like Curds and Whey, as it returns to the Heart; by which Grumes the converging Branches of the pulmonary Artery being obstructed, the Blood's Course thro' that Organ is cut off, and the Animal thereby suffocated. And there are very few Diseases, whether acute or chronic, which prove fatal before they have caused a Peripneumony, or render'd the Blood unfit to pass thro' the Lungs; which it wou'd not be able to do in the healthy Animal, if it was as thick as in the incipient Veins; and therefore the wise Architect has so order'd our vascular Fabric, that all the Juices returning thinner than the Blood, shall be gradually poured into and mix'd therewith in the Veins, before it enters the right Ventricle. But when arrived in the right Ventricle, it there mixes with the highly attenuated Blood of the Heart itself

ſelf from the coronary Veſſels (*per* §. 183.); and even in the Lungs, the watery Vapours abſorbed from the Air in Inſpiration, make up for thoſe diſcharged or exhaled from the Lungs in Expiration: But being by theſe Aſſiſtances enabled to paſs thro' the ſmall Arteries of the Lungs, there will be no Danger of its finding a ready Paſſage thro' all the evaneſcent Arteriolæ ramified from the Aorta, and which gave the greateſt Reſiſtance to the Blood where they form the incipient Veins.

§. 261. From hence we know in what Parts of the Body Life and Health are more immediately, and in the greateſt *Danger* [1] of being interrupted; alſo what Service the *larger* [2] Veſſels and groſſer Humours, with the ſmaller Veſſels and more *ſubtile* [3] Humours, are of to render the Body ſtrong, permanent, pliable, and fit for Motion; we likewiſe from hence underſtand why the Veins gradually diverge and grow ſenſibly larger and more *lax* [4], for the Concourſe and Dilution of the Humours, and this before they return into the Heart.

[1] The Circulation will be in the greateſt Danger of Interruption (1.) in the evaneſcent Branches of the pulmonary Artery (§. 260.); (2.) in the Extremities of all the other Arteries, before they open into the incipient Veins.

[2] This I ſay in Oppoſition to the minute Philoſophers, as *Cicero* juſtly calls them, who affirm, That the human Machine might have been more commodiouſly built than we now find it is, by the moſt good and wiſe Creator. Thoſe Gentlemen place

place the higheſt Point of Health in the Perviouſneſs of the Veſſels, and the Tenuity of the Fluids approaching the Nature of Water: To procure both which, they order plentiful drinking of Tea, Coffee, *&c.* which, like the Enticement of a Harlot, begin very agreeable, and for the preſent recruit all the Actions both of Body and Mind, and excite them to a briſk Activity; but then, like *Venus*, they leave fatal Effects behind them, a Weakneſs of the whole Habit, an Inactivity of the Juices, a Relaxation and Weakneſs of the Fibres, and the whole Train of hypochondriacal Diſorders, extending themſelves even to future Generations.

To enable us to judge how wiſely the Creator has formed ſome of our Juices of a large or groſs Texture, and others of them diminiſhing in ſeveral leſſer Series, we ought firſt to conſider, that in the human Machine there is required one Spring or Principle of Motion by which all the Juices may be propell'd to the ſeveral Parts where they are requir'd; were there to be more Springs of Motion than one, they might be charged with being ſuperfluous, or with diſturbing the Oeconomy by the different Degrees and oppoſite Directions of their Forces, which wou'd endanger the whole Syſtem; for we even find generally but one Heart in Monſters that have two Heads or two Bodies. As but one Heart is neceſſary, ſo it is required that all the animal Juices to be moved thereby, paſs into and mix together in its Caverns or Ventricles; which we find is admirably executed, inſomuch that there is no one Humour moving in the whole Body but what was lately mix'd with the Blood in the Heart.—It was neceſſary for the moving Power of this Spring, the Heart, to be very conſiderable, that it might overcome all the Reſiſtances oppoſed

poſed to it (§. 215.); and for the ſame Reaſon it was neceſſary for the Veſſels next the Heart to be ſtrong, that they might ſuſtain the Impetus of that Muſcle, and propell the Blood by their own Contraction when that of the Heart ceaſes. And as the Force of the Heart hardly extends itſelf beyond the firſt Series of Veſſels, *i. e.* ſanguiferous Arteries and Veins, it follows that the more ſubtile Juices of the Blood muſt be propell'd thro' the ſeveral ſmaller Series of Veſſels by the Force of the ſanguiferous Arteries. Thus the Force of the Heart will be communicated to the ſanguiferous Arteries by the Blood; and by the Contraction of the ſanguiferous Arteries, ſuch Parts of the Blood as are leſs than the red Globules will be propell'd into and thro' the ſmaller Series of lymphatic Arteries. But if the red Parts of the Blood were not larger than the yellow ſerous ones, it would all be forced into the lateral ſerous Arteries inſtead of returning by the Veins, and there ſtop, not being able to enter the leſſer Lymphatics; another Conſequence of which would alſo be a Collapſion of the Anaſtomoſes of the ſanguiferous Arteries and Veins, thro' which Blood paſſes to the Heart naturally in continued Threads.

But the ſmalleſt lymphatic Globules cannot be produced immediately from the larger red ones, any more than the intermediate Lamellæ in the Albumen of an Egg can paſs immediately into the fine cryſtalline Colliquamentum that firſt nouriſhes the Carina; whereas by Incubation for ſome Days, all the albumen is ſo attenuated as to paſs into the Subſtance of the Chick. There are therefore intermediate Series of Arteries, which carry Liquors conſiſting of Particles leſs than the red Globules, and larger than the ſmalleſt lymphatic ones; and theſe we call ſerous Arteries. Here

again

again the ſerous Globules are required to be of a Diameter larger than to enter the lateral lymphatic Arteries ſpringing from the ſerous ones; otherwiſe thoſe laſt wou'd be deſerted, or totally emptied of their Fluid: And Experience demonſtrates, that thoſe ſerous Globules are each ſix times leſs than red ones, (*per* §. 226.) But the ſerous Globules are far from being the ſmalleſt in the Body; for the next Series of Veſſels, or the largeſt Lymphatics, carry Spherules each ſix times leſs than the ſerous, and thirty-ſix times leſs than the red Globules: ſo that the thinneſt and fineſt Juices in the Body ariſe intermediately from the groſs Blood, thro' many Series of decreaſing Veſſels, leſt if the Blood conſiſted entirely of the ſmaller Spherules it wou'd be immediately conſumed, and none left to return into the Heart. Hence in Men who have loſt a great Part of their Blood by a Wound, and being thirſty have indulged themſelves with drinking large Quantities of thin Liquors, we ſee an univerſal Dropſy is ſpeedily the Conſequence. And for the ſame Reaſon frequently ariſe watery Tumours from an Obſtruction of the Veſſels which then only admit the aqueous Parts, which pervade more eaſily than others in the Blood, which ſtagnating in its proper ſanguiferous Veſſels, the aqueous Parts readily paſs into the lateral Vaſcules. Laſtly, we often obſerve the Blood ſo far divided and broke by many Cauſes in pulmonary Conſumptions, that it runs out of the Body in Sweats even to the Deſtruction of the Patient. But on the contrary, if the healthy ſerous and red Globules combine into larger, as they often do in acute Fevers, then the Blood will be all confined in the ſanguiferous Veſſels, and the ſerous ones will be either empty, or ſtuffed with too large Globules, by the increaſed Action

on the ſanguiferous Artery, whence Inflammation, a Loſs of the Secretions, *&c.*

3 We have before obſerved how neceſſary the thicker red Parts of the Blood are, ſince they alone generate its Heat (*per* §. 220.); but it is alſo requiſite for the Blood to contain other ſmaller Globules adapted to the ſeveral leſſer Series of Veſſels. The human Body being built not to ſtand ſtill, but for various, perpetual, and very ſwift Motions, it was neceſſary it ſhou'd conſiſt not of one continued or ſolid Maſs, incapable of yielding, or inflexible to a ſmall Force, but of many ſmall Fibres moving eaſily by the Sides of each other, in their moveable Parts, and ſuſtained or ſecured by the ligamentary Inſertions of their other Parts. But theſe moveable Fibrils muſt be hollow (*per* §. 440.) or elſe they cou'd not be nouriſhed: Therefore it was neceſſary for the Body to be made a vaſcular Compages, not only furniſhed with Veſſels of ſeveral Orders down to the minuteſt, but alſo with Juices of a determinate Conſiſtence and Texture adapted to each Series of Veſſels, in order to pervade them. It was alſo neceſſary for the Parts of ſome Juices to be ſo far attenuated, as to exhale in the Form of a Vapour betwixt the Fibres and Interſtices of every Part, to diſtinguiſh and divide them from each other; and this we ſee is done, not with Water, for that wou'd be too ſluggiſh, and apt to form dropſical Tumours, but by a moiſt lubricating Vapour.

4 It was neceſſary for the Veins to be lax, that they might be eaſily fill'd by the ſmall Impulſe of the leſſer Arteries, and afford room to retain or ſtore up the Blood to ſupply the Heart; they ought alſo to be capacious for receiving the new Chyle, and to allow for the Blood's Rarifaction by Motion, *&c.* And the Figure of the Veins ought to be that of a diverging Cone, that the Blood might paſs

paſs eaſily thro' them as upon an inclined Plane, and ſo paſs to the Heart without Reſiſtance, *(per* §. 260)

§. 262. Some Glands however ſeem to have a different Fabric and Contexture (than at §. 257, 258.); *ſo* [1] that the Artery ſometimes conveys the thicker Parts of the Blood which it carries, by open Anaſtomoſes from the Artery into the fellow Vein; and then Proceeding alone, complicated and folded in its Courſe, at laſt diſtils a particular Juice from the Mouth of its laſt Extremities into a common Receptacle; which Juice, tho' different from the Blood, is nevertheleſs prepared and derived from thence. See *Leal Lealis* on the ſpermatic Veſſels, *apud Euſtach. Opuſc. Anat.* And indeed whoever conſiders that the Stomach, as a hollow Gland, has its Emiſſary, the ſmall Inteſtines, variouſly diſpoſed, for changing, diſſolving, mixing, and ſeparating the Chyle; and who alſo conſiders the ſame Difference of Fabric in the Teſticle, Epididymis, Vas Deferens, ſeminal Veſicles, Urethra and Proſtate, they will perhaps not at all doubt but the ſame Variations may alſo obtain in the ſmaller Glands. Who can pretend to ſay what *operoſe* [2] Fabric may be concealed in the Cortex of the Brain and Cerebellum, ſpinal Medulla, *&c.?*

[1] The Paſſage of the Blood by Anaſtomoſes from the ſpermatic Artery into the Vein was deſcribed after *Galen* and *Euſtachius* by *Leal Lealis*;

and *Raw*, who ſtrenuouſly oppoſed this Communication, found the ſame to be true by the Experiment of Injection, made at my Requeſt. And we have lately had an Account given us of a very evident Communication in the ſpermatic Veſſels, inſerted by Dr. *Mortimer* in *Philoſ. Tranſact.* N. 415. in which Caſe the Injection paſſed from the ſpermatic Vein into the Artery, and from the Artery into the Vein. But notwithſtanding all this, we muſt frankly acknowledge that Accounts have been ſent us from *England*, and elſewhere, and that Experiments have been made with Injections by the moſt diligent and expert Anatomiſts, aſſuring us, that the arterial Branches of the Spermatic wreathed in and out, do only adhere to the Vein, without at all being inſerted into it, or making large Anaſtomoſes therewith. But this we may depend on, that the ſpermatic Artery intermixing itſelf with the Vein, in a Proceſs of the Peritonæum at ſome Diſtance from the Teſticle, does, at its Arrival there, diſperſe into lateral Branches, terminating in ſmall viſible Anaſtomoſes with the correſponding lateral Branches of the Vein, into which the red Parts of the Blood are tranſmitted, while the ſerous and lymphatic Parts are carried by the ſmaller Arteries into the Teſticle, whoſe glandular Pulp or Subſtance is therefore pale and bloodleſs, while its including Tunics are abundantly ſpread with ſmall Blood-veſſels; ſo that while the Membranes are plentifully ſupplied with Blood, the Pulp of the Teſticle is ſupplied with pellucid Juices by Arteriolæ much ſmaller than the ſanguiferous, and into which the *Ruyſchian* Injection will not enter. The ſame Structure is alſo obſerveable in the Cortex of the Brain, and perhaps the ſame Mechaniſm may be repeated in ſeveral other Viſcera, where our Eyes and Microſcopes are not able to penetrate.

Thus

Thus have we in general conſider'd and determin'd the Laws and Circumſtances of Secretion (§. 253.); but we have reaſon to ſuſpect that there are many Variations and Particulars not yet diſcover'd to us: For we even know in reality that Secretions may be made from a Vein, by what we obſerve in the Porta of the Liver from whence the Bile is ſeparated. The diligent Anatomiſt *Raw* formerly ſuſpected that the medullary Oil of the Bones was ſecerned from the ſmall Viens; and it is certain that the oily Cells have a very open Communication with the Veins, by the ſpeedy Return of their Contents that way: We are therefore not yet clear in the Buſineſs of all the Glands and their Secretions; and there are probably many Artifices concealed from us in this Branch of Nature, which we have not ſo much as ſuſpected or thought of.

§. 263. Since therefore *Hippocrates*, *Wepfer* and *Malpighi* have, from an accurate Survey of the Cortex of the Brain, compared its Structure to that of a Gland, it is evident they ſaw ſo much Similitude bewixt the Fabric of this Part and that of other Glands, that they made no doubt but the Cortex of the Brain was truly glandular: *Malpighi* has even pronounced the Glandules of the Cortex to be of an oval Figure, and ſomewhat angular by their Compreſſion on each other; and that the ſmall ones being diſpoſed in Curves and attached together, form larger oval Glandules, which again combine into ſtill larger; which laſt being collected and diſpoſed in Convolutions like the Inteſtines, immediately compoſe the outer Part of the Cortex; ſo that the ſmalleſt

Branches of the carotid and vertebral Arteries being here convoluted into the Structure of a Gland, might diſtill from an infinite Number of their very minute Ducts or Mouths, the moſt ſubtile Parts of their Blood, into their proper Follicle or Cell, to be convey'd from thence into the Emiſſary, while the remaining groſſer Parts of the Blood are returned by the ſmall Veins into the Sinus's. See §. 236.

§. 264. This Opinion of *Malpighi* [1] is favoured by the *Eye* [2] and *Microſcope* [3]; by the Brain appearing to divide itſelf into little Heaps, like Glands, after it has been *boiled* [4]; from the diſtinct Appearance of the Furrows betwixt thoſe round and prominent Heaps, by pouring *Ink* [5] on the Cortex, and then wiping it off; from the morbib Concretion of the Cortex, into a ſtony Subſtance ſhaped like a *Mulberry* [6]: To theſe we may add the Degeneration of the contuſed Cortex into a ſort of glandular *Fungus* [7], ſprouting up through the Hole or Fracture of the Cranium, and the evident Change of the ſame Part into *Spherules* [8] or Hydatids from a dropſical Diſorder; all which ſeem to prove that this Part of the Brain has the ſame Fabric with other Glands, only much more ſubtile or minute.

[1] Who holds that the Brain is compoſed of Lobes, which are again made up of Lobules, and thoſe laſt of Follicles, upon the proper Membranes of which the ſmall Arteries are diſtributed, and diſtill the Spirits or moſt ſubtile Juice of any in the Body

Body into the Cavities of the ſaid Follicles, from whence the Spirits flow by their proper Emiſſaries, the nervous Tubuli or Fibrillæ.

[2] Such is the Colour, Humidity and pulpy Softneſs of the Brain, and ſo near a Reſemblance has it to the Fabric of other Glands, that it was ranked among thoſe Parts by *Hippocrates* in his Book of Glands. But it does not follow, that becauſe the intermediate Subſtance of the Brain betwixt its Arteries and Veins appear glandular, that therefore it is compoſed of Follicles; ſince we know that many Glands are compoſed of mere lateral Vaſcules in many other Parts of the Body, and therefore the ſame Mechaniſm may obtain here.

[3] Tho' M. *Lewenhoec*'s Microſcopes were not very well adapted to examine pellucid Objects, he cou'd nevertheleſs obſerve, with his laſt or moſt convex Lenſes, that the Brain conſiſted of round, ſplendid, and as it were oily Corpuſcles, reſembling little Glands. But *Malpighi* preferr'd the Microſcopes made in *England* by the expert Optician *J. Marſhall*, ingeniouſly contrived with three or four Lenſes, as deſcribed in the *Philoſophical Tranſactions*, and in *Harris*'s *Lexicon Technicum*. But *Lewenhoec*'s Microſcopes were ſingle, conſiſting of but one Lens, permitting the Diſtance of one Semidiameter of the Lens betwixt the Object and Glaſs; which Diſtance is too inconſiderable in the ſmaller Lenſes to give the Object Light enough to be clearly viewed by the Eye of the Inſpector. *Malpighi* therefore uſed the double Microſcopes from *England*, by which he cou'd percieve the ſmall Arteries of the cortical Subſtance terminate in very minute Circles, their Intervals appearing to be fill'd up with little Grumes or round Bundles; and moſt of the Learned after him either ſaw, or imagin'd they cou'd ſee theſe round glandular Cor-

puſcles in the Cortex, which were in reality no more than its pellucid Subſtance terminated by the Blood-veſſels on every Side.

2 This Artifice was uſed firſt by *Malpighi*, and then by *Vieuſſens*; which laſt boiled the Brain in Oil for the Space of ſeveral Hours, becauſe boiling Oil is thrice as hot as boiling Water, and therefore makes the Brain much harder by boiling; after the Pia Mater had been firſt ſeparated from it on all Sides, he perceived the whole Surface of the Cortex beſet with little round Tubercles or Inequalities: But it muſt be conſider'd, that the Parts of the Brain do not retain their natural Diſpoſition after they have been thus boiled, ſo that we can rely but little on the Experiment, which at moſt only demoſtrates, that there are little Portions of the Cortex diſtinguiſhed from each other by the Pia Mater, which deſerts or ſhrinks from them by boiling.

3 *Malpighi* having removed the Pia Mater, poured Ink upon the unequal Surface of the Cortex of the boiled Brain, and upon wiping it off, there remained black Lines or Furrows like the Marſhes of a Net, betwixt which appeared white oval Corpuſcles protuberant; but *Ruyſch* eaſily demonſtrates, that the Ink thus deſcends only into the Sulci formed by the Veſſels, and therefore only ſhow the Courſe of the ſmall Veſſels contracted.

4 *Wepfer* has an Obſervation on ſome Parts of the Brain petrefied or formed into a ſtony Subſtance full of little Eminencies like a Mulberry; which ſeems to be a ſtrong Argument in Favour of *Malpighi*'s Notion of the Brain being glandular: For a Juice or ſoft Subſtance does not aſſume any proper Figure of its own by Concretion, but upon petrefying it takes the Shape of the hollow Cavity or Receptacle in which is was confined. Therefore

fore from the Appearance of the petrefied Juices in the Cortex of the Brain, it ſeems to follow that the Humours thus changed retained the Figure of the glandular Follicles into which they were ſecerned before Petrefaction; which Follicles, thro' originally inviſible from their exceeding Minuteneſs, are yet by this morbid Indiſpoſition diſtended and render'd conſpicuous by the congeſted Matter.

5 When the Dura Mater has been wounded by any Accident, the Brain uſually protrudes itſelf thro' the Opening in that Integument, and forms a ſort of fungous Excreſcence upon the Lips of the Wound; ſo that the narrow Part of the Cortex coming through the Dura Mater is like a Stalk, but the external Surface of the Fungus is beſet with rough Tubercles like little Buttons, or the Heads of Muſhroons. But theſe excreſcent Tubercles are thought to be the glandular Portions or Follicles of the Brain diſtended, enlarged and ſupported by their Peduncles or emiſſary Ducts, probably after the manner of Grapes. But in effect, theſe Tumours ſhow no more than that the arterial Fluid has a great Niſus or Impulſe thus to protrude Matter, and diſtend the Parts; and it is certain that a vaſcular Fabric or Compages may be equally diſtended by that Force as a glandular Structure.

6 Another cogent Argument in favour of the glandular Fabric of the Cortex, is the Appearance which it makes in an Hydrocephalus, when the Sutures ſeparate ſpontaneouſly from each other; and after opening the Cranium, removing its Integuments and inſpecting the Cortex we frequently obſerve it beſet with little Veſicles or Hydatids, diſtended with a pellucid and reſplendent Lymph or Serum; and upon opening each of them by Puncture with a Needle, they ſeverally diſcharge

a ſingle Drop of Liquor, without communicating with each other. This Liquor probably ariſes from the moiſt Vapours, which are naturally very ſubtile, being redundant and collected into a ſenſible Water; but *Ruyſch* has, in his latter Preparations demonſtrated, that the cellular Membrane is inſinuated all over the Brain, betwixt the Tunica Arachnoides and Veſſels of the Pia Mater, in which cellular Fabric he has ſometimes obſerved an oily Fat contained; and therefore he attributes the Appearance of thoſe Hydatids to a Diſtention of the Cells with an aqueous Lymph. (*Vid.* §. 82.) Even every Part throughout the whole Body is ſurpriſingly inveſted with communicating Cells, which become very turgid and conſpicuous by Diſtention either with an aqueous or oily Humour from the Blood; and wherever this cellular Expanſion is continued there the Parts are liable to dropſical Tumours or Diſtentions. A Man who had his Legs ſwell'd to a moſt monſtrous Size by the Diſtention of this Membrane, happened to break his Shins by accident, ſo as to wound this cellular Membrane; in conſequence of which all the diſtending Water ran out, and left the Skin collapſed about his Legs, that one might have imagined them inveſted with Bags. I therefore make no doubt but that as this Membrane is extended with all the Veſſels and Fibres of the other Parts and Viſcera, ſo it is likely to be in the Cortex of the Brain, where it may form Hydatids as in the other Parts.

§. 265. But whether the ultimate little Branches of the cortical Veſſels be directly continued into the fibrous Subſtance of the Brain (§. 269.), as *Ruyſch* endeavours to prove by

by his Preparations, cannot be determined by any *valid* [1] Argument; becauſe thoſe evaneſcent Vaſcules are too minute to be any way perceived by the Eye, and even *Ruyſch*, by his moſt accurate and fulleſt Injections of this Part, could never tinge the medullary Subſtance of the Brain red, but it always retained its native white Colour (*per* §. 262.). It muſt yet be confeſſed that this Opinion of *Ruyſch* ſeems very probable for many *important* [2] Reaſons, which we ſhall hereafter mention (§. 269. *& ſeq.*); but which ever Opinion takes Place in the cortical Fabric of the Brain, whether that of *Malpighi* or *Ruyſch*, the Effects or Conſequences will be found nearly the ſame in both.

[1] We before obſerved what might be objected to the Preparations and Experiments of *Ruyſch* in §. 236.; ſince it appeared that a very great Part of the moſt tender Fabric in the Cortex was that way deſtroyed, and only that Part left entire which lay next the Pia Mater, and was fill'd with the durable ceraceous Injection, which he could never force into the ultimate Series or ſmalleſt Branches of the Veſſels; and therefore it cannot be thence inferred that there are no intermediate Glandules betwixt the Extremities of the Arteriolæ and the Beginning of the Nerves; he demonſtrates plainly that there are infinite Numbers of ſmall Veſſels in the Cortex, but by no means proves there are nothing elſe but Veſſels.

[2] There are in ſhort ſuch probable Reaſons advanced for the Opinion of *Ruyſch*, that I muſt at length come into his Notion entirely; for if there were

were any of *Malpighi*'s intermediate Follicles betwixt the evaneſcent Arteries of the Cortex and the incipient Tubuli or Fibres of the Medulla, they would unavoidably intercept and hinder the arterial Preſſure of the Juices into the Nerves, by which the whole Maſs of nervous Fluid would be retarded in its Paſſage through the Medulla of the Brain; whence muſt follow dangerous Conſequences, even fatal to Life, ſince Life immediately depends on the free and uninterrupted Influx of the nervous Juice from the Brain and Cerebellum. Such a Mechaniſm is alſo repugnant to the wiſe Conduct of Nature which ſhe uſes in other Parts, where we obſerve the ſecretory Ducts continued immediately from the Arteries, and conveying their Juices thence from the Blood without any Delay; whereas in all Glands, where Secretion is performed in Follicles, the Juices are not ſecerned and diſperſed equally, but there are a ſort of Paroxyſms or Fits of an increaſed and diminiſhed Secretion, as we obſerve in the Bile, Semen, Urine, *&c.* But there are no ſuch Fits of an increaſed and diminiſhed or irregular Secretion in the Brain, and it would be dangerous for ſuch to be there. We know the Follicles propell their contained Juices by a membranous Contraction, and not by the protruſive Force of the Arteries; and that their Contraction is not conſtantly but at Intervals, and therefore *Malpighi*'s Doctrine would infer alternate Repletions of the Nerves from their Follicles, ſo that we ſhould thus be ſenſible and inſenſible at Intervals. The Subſtance of the Brain ſo very exactly filling the whole Cavity of the Cranium, is alſo a ſufficient Evidence there can be no Accumulation or Contraction in any Cells of the Cortex; and if there were intermediate Glandules in that Part, we ſhould hardly ſuffer ſuch an Eclypſe or ſudden Loſs of

all

all the Functions depending on the Brain and Nerves, upon removing the arterial Preſſure of the Blood from the Encephalon, as in bleeding, *&c.* But we experience that this Preſſure of the Blood from the Heart and Arteries is no ſooner deſtroyed or impaired, but that very Inſtant all the Functions of the Brain ceaſe, and return again as ſuddenly when that arterial Preſſure is reſtored. Laſtly, we hardly ever meet in the Brain, even of 80 Years ſtanding, with thoſe Diſorders ſo frequent in other glandular Parts, which have a much ſtronger Fabric.

§. 266. The Extremities then of thoſe ſmalleſt arterial Branches (§. 265.) or of thoſe little glandular Follicles (§. 263.) ſend out ſmall white Threads, which, becoming more compact, unite and form the Corpus Calloſum and Medulla of the Brain, which laſt is cloſely inveſted by and connected to the *Cortex* [1] or cineritious Part, both in the Brain and Cerebellum; ſo that wherever the cortical Part terminates, there the callous or medullary Part always begins.

[1] Which ought not to be thought as deep as the Sulci of the Brain, in which the Pia Mater inſerts itſelf; for I have frequently demonſtrated that the whole Cortex hardly ever exceeds the Thickneſs of a Finger's Breath.

§. 267. But which ever Way theſe Parts communicate, the cortical Machine is ſo accommodated or adapted to the medullary Subſtance, that it adheres not only to the Sur-

Surface both of the Brain and Cerebellum, but alſo to the outermoſt Appendices of the Corpus Calloſum, and to the Ventricles, and is even *continued* [1] with the ſpinal Medulla, and the oblong Tract or Portion thereof, which is without the Brain; but ſo that in this latter, the *cortical* [2] is included in the medullary Part, and intercepts a ſort of Sinus in its middle, in which a vaſt Number of ſmall Arteries are ramified down the whole Extent of the ſpinal Medulla.

[1] The cortical Subſtance is not only continued down the middle of the whole ſpinal Medulla, but alſo abounds there more or leſs in Proportion to the Number of Nerves ſent out; whence it is too that the ſpinal Medulla is very thick even at the Os Sacrum, where one might imagine it muſt have been exhauſted by detaching ſo many and large Nerves in the Way,

[2] It was altogether neceſſary for the medullary to include the cortical Subſtance in the Medulla Spinalis; becauſe the medullary Fibres ariſe every where directly from the cortical ones; but if the cortical Subſtance had been placed without-ſide the Medullary, then the Fibres of the laſt muſt have concurred towards the Center, and there have met; but they are deſigned not to meet but to be ſent out in Nerves, and therefore they would then have perforated the Sides of each other, *i. e.* the medullary Fibres of one Side forming Nerves, would ſend them through the cortical and medullary Subſtance on the other Side of the Spine, ſo that the Nerves of the right Side would have ariſen from the left, and the Reverſe. To prevent theſe Inconveniences and Embarraſſments Nature has inverted

verted the Fabric of the Brain in the ſpinal Medulla, placing the cortical or cineritious Subſtance withinſide, and the medullary Subſtance without, that the Fribes of the laſt might be collected like the Radii of a Circle, and formed into Nerves. *Vid.* §. 237.

§. 268. So that wherever this Compages (§. 263.) of inviſible Arteries and correſponding *inviſible* [1] Veins is continued, throughout the Encephalon or Brain and its Appendages, there we alſo of neceſſity meet with this cortical Subſtance, as well in the Receſſes, Convolutions, Diviſions, Interſtices and Appendices, as in the external Superficies thereof next the Cranium.

[1] No ſanguiferous Veſſel was ever obſerved in the cineritious Part of the Brain; none of thoſe Arteries belong to it which go down perpendicularly from thoſe of the Pia Mater, which are diſtributed in the Sulci of the Brain. Nor has the cortical Subſtance any ſanguiferous Veins, as *Raw* and *Drelincourt* have obſerved; and yet if we conſider what a vaſt Quantity of Blood is brought to the Brain by the Arteries, the greateſt Part thereof muſt be returned by the Veins of the Pia Mater into the Sinus's, ſince the Arteries do not ſend any of their Blood immediately into the Sinus's (*per* §. 234.) In a Man that is hang'd the Blood finds Admittance to the Brain by the carotid Arteries, which are deeply ſeated, but is prevented from returning again by the Veins, which, lying near the Skin, are compreſſed by the Rope; thus all the Arteries and Veins of the Pia Mater will be diſtended with Blood as if they had been fill'd with the Injection

jection of *Ruyſch*; but notwithſtanding the Sinus's and Veins are thus turgid and diſtended, there is not the leaſt Redneſs to be obſerved in the Subſtance of the Cortex; and therefore it follows, that all the red Blood circulates only from the ſanguiferous Arteries into the ſanguiferous Veins of the Pia Mater, whence it paſſes into the Sinus's of the Dura Mater. But though there are no ſanguiferous Veſſels in the Subſtance of the Cortex, yet there are ſmaller ones which convey Juices thinner than the Blood, as we are aſſured from the Nutrition and Growth of this Part which enlarges in Proportion to the reſt of the Body, which could not be effected without a Diſtention by the Juices impell'd by the Heart; and the Truth of the Fact is confirmed by all the Evidence that Reaſon and Analogy can afford; and therefore this ſeems to be the genuine Fabric of the Cortex: *Viz.* from the ſanguiferous Arteries of the Pia Mater ariſe (1.) ſanguiferous Veins which open into the Sinus's, and (2.) ſerous Arteries which admit all but the red Parts of the Blood, and again ſend off ſmaller lymphatic Arteries, and correſponding ſerous Veins, ſo that the ſerous Artery tranſmits its groſſer and yellow Parts into ſerous Veins, and the more ſubtile and pellucid into lymphatic Arteries; which again ſend out many other ſmaller Series of lymphatic Arteries, till the laſt Series of them terminate in the nervous Tubuli or medullary Emiſſaries of the Brain. The infinite Number of Anaſtomoſes or Communications betwixt the Branches of the ſeveral Series or Strata of pellucid Arteries in the Cortex, is the Reaſon that this Secretion and the Action of ſome of the Nerves does not ceaſe when Part of the cortical Subſtance has been ſuppurated or otherwiſe deſtroyed; becauſe the innermoſt Strata of Arteries are ſtill ſupplied with their Juices by the lateral Anaſtomoſes

naſtomoſes or Communications of their Branches; ſo that if the Medulla of the Brain be not totally deprived of all its cortical Subſtance in any Part, the Secretion will ſtill continue there, and ſupply the medullary Tubuli, notwithſtanding the Pia Mater and ſuperior Veſſels are deſtroyed or ſuppurated. Theſe Anaſtomoſes of the Veſſels ſeem to be diſpoſed in the manner of the Circulus Arterioſes Williſianus.

Of the Medulla of the Brain.

§. 269. SINCE therefore Part of the Medulla ariſes from every Point of the Cortex, the former muſt of neceſſity be very fine and tender at its Origin; but conjoining in its Progreſs or Deſcent with the other neighbouring Tubuli like itſelf, it becomes gradually more *large* [1], compact, and viſible, ſo as to conſtitute the Medulla and Corpus Calloſum of the Brain, with the Crura of the Medulla oblongata, the Thalami of the optic Nerves, the Medulla oblongata and its Crura, Productions and *Protuberance* [2], with the Medulla of the Cerebellum and its Continuation into the Medulla oblongata of the Brain, which, *uniting* [3] herewith, forms the Corpora Pyramidalia and Olivaria, and then extends itſelf down in the ſpinal Medulla, even to the ſecond Vertebre of the Loins, where it is divided by Integuments from the Pia Mater into diſtinct

distinct Nerves, which are dispersed from this last Head or Origin of them, like a Horse's Tail, as it is also named; and lastly, it is from this medullary Substance, lodged in the Cranium and Cavity of the Spine or Chain of Vertebræ, that all the *Nerves* [4], in any Part of the Body whatever, take their Origin.

[1] We are not able to discern one of the smallest or most simple Fibrills of the Medulla arising from the Cortex, even by the best Microscopes; and the little sanguiferous Arteries, which are by many Series larger than the Tubuli or Fibrills of the Medulla, cannot be perceived by the naked Eye: But when many of those minute Fibrills of the Medulla conjoin into a Fasciculus or Stratum of a hundred or a thousand, *&c.* we can then perceive them under the Form of the medullary Substance of the Brain.

[2] The Creator seems to have framed the Brain with so many Eminences and Convolutions, that the cortical Substance might have the greatest Extent of Surface, and that the greater Number of medullary Fibres might arise from it, and be from thence distributed in distinct Orders or Classes, without interfering together in their Courses.

[3] There is not one, even of the smallest Nerves, which arises immediately from the cortical Substance either of the Brain or Cerebellum, nor even from the medullary Substance of either of them separately; but the Nerves all arise from the Medulla oblongata formed by the Conjunction of the Medulla of the Brain and Cerebellum.

[4] We ought not strictly to confine all the Nerves to so narrow Bounds as forty Pair only; for in each Fasciculus or Nerve of those Pairs, are con-

contained an infinite Number of other Nerves diſtinguiſhed by their proper Membranes, and thence diſperſed into all the ſolid Parts of the Body, which they conſtitute. So that in the human Body, as the incomparable *Sydenham* wiſely obſerves in treating of hypochondriacal Diſorders, we meet with two Syſtems or Principles of Motion combined together; *viz.* (1.) the external or vaſcular Syſtem, on which Life depends; and (2.) the interior nervous Syſtem for Senſation, *&c.* of both which Syſtems the whole loco-motive Animal is compoſed.

§. 270. But that the Filaments which compoſe all theſe Nerves, were originally ſeparate and diſtinct from each other in the Brain, notwithſtanding they ſeem there conjoined into one continued or compact Maſs, will be ſufficiently apparent to any one who conſiders (1.) their Origin, Compoſition, and Progreſs from the *diſtinct* [1] Portions of the Cortex; (2.) their Appearance in the Brains of *Fiſh* [2], Hares, Sheep, and Oxen, either crude or boiled; in which the medullary Fibrills are manifeſtly obſervable like depreſſed Cylinders diſpoſed in Striæ, by the Sides of each other, like the Teeth of a Comb; (3.) the ſmall *ſanguiferous* [3] Veſſels inſinuating betwixt the medullary Fibrills, and making a manifeſt Diviſion or Separation of them; (4.) the Invertion or Interpoſition of the Cortical within the ambient *medullary Subſtance* [4] of the Medulla Spinalis; (5.) the Courſe of the white Fibres diſperſed through the middle of the cortical Sub-

ſtance, which is *continued* [5] in the Back-part of the ſpinal Medulla before its Egreſs from the Cranium, and are alſo obſervable in the Sides of the ſame ſpinal Medulla, near its Origin within the Cranium, but are beſt ſeen in the Appendices of the Corpus Calloſum and in the Cerebellum itſelf; and (6.) laſtly, the Collection and Diſtribution of theſe medullary Fibrills, firſt into the Medulla Oblongata, and then into all the *Nerves* [6] of the Body.

[1] The cortical Subſtance, we obſerved, is variouſly diſpoſed in diſtinct Convolutions, and terminates internally where the medullary Fibrills begin; whence it follows that the Combination of medullary Fibres muſt have aroſe from diſtinct Portions of the Cortex, *per* §. 266.

[2] The medullary Fibrills appear moſt diſtinct in the Brains of ſuch Animals as have a very ſwift Motion of their Muſcles, and in thoſe Brains they are obſerved in Striæ, or diſpoſed like the Teeth of a ſmall Comb, as *Malpighi* has deſcribed them in Fiſh.

[3] If you divide a Portion or Convolution of the cortical Subſtance tranſverſly, after the Brain is injected, there does not appear ſo much as one red Spec or divided Blood-veſſel; but if you divide a Portion of the medullary Subſtance in the ſame manner, you will perceive innumerable red Points betwixt the milk-white Fibres of the Medulla; which red Points are divided Veſſels, which come down perpendicularly from the Pia Mater, where it inſinuates betwixt the Gyri of the Cortex, and are not diſperſed in a reticular manner among the Subſtance of the Medulla, but ſeem to run parallel with the medullary Fibres, to communicate

Warmth

Warmth to this coldeſt and moſt exanguious Part of any in the Body: But theſe Veſſels muſt of Neceſſity divide and diſtinguiſh the medullary Fabric into Faſciculi or Portions; and in the ſame Manner we obſerve the optic Nerve is perforated in its Center by a ſmall Artery of its own, which divides the medullary Subſtance of that Nerve.

4 The internal or cineritious Subſtance of the ſpinal Medulla, appears (by the *Ruyſchian* Art of injecting) all over beſet with red Veſſels, like the Cortex of the Brain, with its Pia Mater. This vaſcular Plexus in the midſt of the ſpinal Medulla is the Seat of a Diſorder ſimilar to the Hydrocephalus, being a Dropſy of the internal cortical Subſtance of the ſpinal Medulla, ſo often fatal to Infants, and deſcribed by *Tulpius* and others by the Name of Spina bifida; in which, as in the Hydrocephalus, the bony Caſe is divided and vaſtly diſtended, as the ſtagnant Lymph is accumulated. *Ruyſch* has demonſtrated Fibrills paſſing in a diſtinct and tranſverſe Courſe from the cineritious to their Inſertion in the external or medullary Subſtance of the ſpinal Marrow.

5 In every Proceſs or Protuberance formed by the Brain before the Medulla oblongata, Nature ſeems to have ſtudiouſly placed ſome of the cineritious Subſtance; as we may plainly perceive in the Nates, Teſtes, Corpora Olivaria, and Pyramidalia, *&c.*

6 The medullary Subſtance of the Brain ariſes in diſtinct Portions from the cortical Part, and is afterwards divided or ſplit into the ſeveral diſtinct Nerves of the Body: But any one of thoſe Nerves being macerated in Water, divides or ſplits into a thouſand Fibres or ſmaller Nerves, which were no leſs diſtinct from each other in the Subſtance of the Brain than in the Body of the Nerve. In ſhort,

the nervous Syſtem may be well compared to a Tree, the Trunk of which is repreſented by the Medulla Oblongata, the Root by the medullary Subſtance of the Brain and Cerebellum, and the Branches by the ſeveral Nerves of the Body: But there is not any diſtinct Twig, or even Fibre, in the Branches of a Tree which were not alſo diſtinct from each other in the Trunk; nor any diſtinct from each other in the Trunk which were not equally ſo in the Root, as Dr. *Grew* has long ago demonſtrated. We do not as yet enquire whether the medullary and nervous Fibres are pervious and tubular, but we here undertake to ſhew that the Medulla of the Brain is not a confuſed Maſs like a Sponge, but an Aſſemblage of ſmall Threads diſpoſed in a diſtinct Order.

§. 271. The Courſe of theſe medullary Fibres is perceived to be as follows: (1.) Ariſing in diſtinct and very ſlender Fibrills from the ſpherical *Cortex* [1] inveſting the Medulla, they firſt converge towards the Center of a Sphere, and form the whole medullary Subſtance, from whence again diverging, the ſuperior Fibres are collected into the *Corpus Calloſum* [2] and Fornix, while the lower Fibres meet in the anterior and poſterior *Crura* [3] of the *Medulla Oblongata* [4], and in the annular Protuberance; (2.) thoſe of the Cerebellum, which ariſe like the former, *converge* [5] and then unite with the two preceding, but they all combine in their three different Directions; (3.) all theſe Claſſes of medullary Fibres uniting into one Faſciculus or Bundle, compoſe the

the *ſpinal Medulla* [6]; (4.) the like ſort of medullary Fibres ariſing all round from the internal or cineritious Subſtance of the ſpinal Medulla, unite with every Point of the inner Surface of its white Medulla from the Encephalon, and give the laſt Increaſe to its Bulk.

[1] The Pia Mater forms many Arches, and gives the Cortex of the Brain a ſpherical Figure, that it might afford Riſe to the greater Number of medullary Fibres.

[2] The medullary Fibres converging from all the upper Parts of the Cortex, unite together and form the Corpus Calloſum, with its Fornix or arched Roof; after which they meet with a lower medullary Fibres and compoſe the third Ventricle: But the inferior Fibres of the Medulla terminate in the anterior and poſterior Crura of the Medulla Oblongata, which combine with the medullary Fibres of the Cerebellum and the annular Protuberance; ſo that the Corpus Calloſum and Medulla Oblongata may be reckoned the two Trunks or Foot-ſtalks to the Medulla of the Brain.

[3] The Crura may be diſtinguiſhed into two or four, according as the Lobes of the Brain are divided laterally, and into anterior and poſterior.

[4] This is compoſed (1.) of the converging Medulla, which is diſtributed into the nine Pair of Nerves: (2.) Of the Medulla from the Cerebellum, whence paſſing to the fourth Ventricle it aſcends and unites with the Medulla Oblongata: (3.) Of the medullary Fibres from the upper Parts of the Brain, which paſſing over thoſe of the nine Pair of Nerves, terminate in the ſpinal Medulla.

[5] Thus the Fibres of the Cerebellum all uniting with thoſe of the Brain compoſe the Medulla Oblongata; and where the Medulla of the Cerebrum and Cerebellum meet together they form the annular Proceſs or Protuberance; and the fourth Ventricle ſeems chiefly deſigned to keep the Crura of the Cerebellum diſtinct.

[6] This Part is compoſed (1.) of the remaining Fibres from the Medulla Oblangata, after it has detach'd the nine Pair of Nerves; (2.) of thoſe Fibres from the Cerebellum which did not aſcend into the Medulla Oblongata; and laſtly, (3.) of its own Fibres which come from its internal cineritious Subſtance and unite with the former.

§. 272. Since therefore the Fabric or Structure of theſe Parts is apparently ſuch as we have here deſcribed, the Reaſon of the *Bulk* [1], *Figure* [2], and *Poſition* [3] of the cortical Subſtance it thence obvious; and it is alſo thence evident that thoſe Parts could not well perform their Office without the *Cavities* [4] we call *Ventricles* [5], the Neceſſity of which in the Brain is therefore apparent, ſince at the ſame Time that they prevent one Part of the Brain from injuring the other, they alſo give a free Liberty and Communication betwixt the whole Subſtance of the Medulla; from thence alſo appears the Reaſon of ſo many Protuberances obſerved in different Parts of the Medulla, as new Supplies of medullary Fibres ariſe from different Quarters and Directions.

[1] It was neceſſary for the cortical Subſtance to be more extended than the medullary, becauſe but a few

a few medullary Fibres ariſe from a large Portion of the Cortex; as is apparent in the medullary Peduncles of the Cerebellum, being no larger than ones Finger, when the Cortex of the Cerebellum, whence they ariſe, is full as large as ones Fiſt. Add to this, that every Point of the Cortex is an Aſſemblage of the ſeveral Series of Veſſels diſpoſed in Strata, from the ſanguiferous down to the minuteſt inviſible ones correſponding to but one ſingle Point or Fibrill of the Medulla, which is therefore the Emiſſary of the ultimate Arteriolæ.

[2] The human Brain was advantageouſly formed of a ſpherical Shape, becauſe under a Surface of that Figure is contained the moſt Matter of any; and it was abſolutely neceſſary for the Brain to be very large, as being the Foundation and Origin of all the other Parts of the Body, to which it is continued by the nervous Filaments; the Courſe and Diſtribution of which Nerves are more beautifully repreſented by *Euſtachius* than *Lanciſi* was able to explain them.

[3] This appears from the Conveniency of the ſeveral Series of Vaſcules being expanded in Strata one within the other, which could not have been done in a plain Surface, nor in a membranous Expanſion. And the cortical Subſtance was alſo placed without-ſide of the Sphere, becauſe there every concentric Circle is larger than towards the Center; ſo that by this Means, ſuppoſing the Cortex every where three Lines thick, it will be thrice as much as the Medulla, which Proportion is pretty near the Truth.

[4] The Ventricles of the Brain are not empty Spaces in the living Animal, as they appear to us by opening and dilating them in anatomical Demonſtrations; but whilſt confined in the Cranium they are collapſed or cloſe together, only they are

ſeparated or fill'd with a moiſt Vapour or Dew: And the ſuperior Concavities of the Ventricles cloſely adapt themſelves to the lower Eminences of the ſame, ſo as to leave no intermediate Space. 'Tis true theſe have been thought by ſome to be empty Cavities, and there are many other ſuppoſed Cavities in the Body, which are void Spaces only in Imagination. The Cavity of the Thorax is entirely fill'd with the Lungs, the Stomach and Bladder contract to the Quantity of their Contents, and the Mouth can ſo cloſe and approximate its Parts as to retain no Air or any Liquor, forcing its Contents back and down into the Gula for Deglutition.

[5] *Galen* teazes himſelf wonderfully to give a Reaſon why the Hemiſpheres of the Brain are rather made hollow than ſolid and Compact. The Deſign of the two anterior Ventricles, which are the largeſt, ſeems to be for the more commodious Paſſage and Diſpoſition of the medullary Fibres from the cortical Subſtance, as the former ariſe every way from the latter, converge towards a Center, and then go out of the Brain. For without this Contrivance one of the Inconveniencies following wou'd have enſued, *viz.* that either the Head and Brain muſt have been expanded flat like a Table, conſiſting only of two Strata, one medullary, and the other cortical; or elſe the Medulla muſt have been placed withoutſide the Cortex, which wou'd be inconſiſtent with the Deſign of the ſpherical Figure of the Brain N°. 2. preceding. We alſo know that in ſolid Spheres, Fibres ariſing from the Circumference, and converging towards a Center, muſt perforate each other laterally in order to form Nerves, as we obſerved in ſpeaking to the Medulla ſpinalis, §. 267. The third Ventricle of the Brain, a Foſſa, placed betwixt the

two

two posterior Crura of the Medulla oblongata, arises from mechanical Necessity, since the round Bodies of the Thalami of the optic Nerves cou'd not well touch, or come into Contact with the rest of the Brain without an intermediate Hiatus or Separation. The fourth Ventricle, which is a perpendicular Fossa betwixt the Conjunction of the Crura of the Cerebellum and Medulla oblongata, the upper Part of which Fossa is from its Shape termed *Calamus scriptorius*, does also arise from the same mechanical Necessity. The Ventricles of the Brain have also many Uses or Advantages in Life, such as the perpetual Exhalation of a thin Vapour, or moist Dew, to distinguish and separate the medullary Fibres from concreting or adhering to each other; and to convey those moist Vapours, when turned into Water, to the Infundibulum and pituitary Gland to be absorbed; as also to receive the reticular Expansion of sanguiferous Arteries, termed *Plexus choroideus*, which communicates Warmth to the cold Substance of the Brain.

§. 373. But it is highly probable that the medullary Fibres of the *Cerebellum* [1], which sends out no Nerves from its Medulla, ascend upwards from their Conjunction with the Medulla oblongata towards the anterior Part of the same Medulla of the Brain, where the several Pairs of Nerves are thence detach'd, and there joining with those Nerves, are thence continued with them to the several Parts of the Body; the Fibres from the Brain and Cerebellum being all the way very distinct from each other in their Origin, Progress or Distribution, and Offices: And this Commerce or

Inter-

Intercourſe betwixt the Fibres of the Brain and Cerebellum will evidently appear to one who conſiders the various *Inſertions* [2] of the medullary Part of the Cerebellum into the Medulla oblongata of the Brain, and the *Increaſe* [3] of the latter thence ariſing; as alſo from conſidering the Return of the ſpinal Nerve from the bony Caſe of the Vertebræ into the Cranium, there to unite itſelf with the Nerve of the eighth Pair. But thoſe other medullary Fibres of the Cerebellum, which are not thus detach'd with the Nerves, are ſo *intermix'd* [4] with the Fibres of the Brain, that there is not perhaps a ſingle Point in the whole Medulla oblongata and ſpinalis, in which there are not as well Fibres of the Cerebellum as of the Cerebrum intermix'd; and therefore both are probably extended together in like manner in the Body of every Nerve for quite different and diſtinct Offices or Effects.

[1] The Brain or Cerebrum ſeems to be the Seat of animal Action in the human Body, and the Cerebellum the Seat of the vital Actions or Functions (*per* §. 600.); but the Faculties of Senſation and voluntary local Motion cannot ſubſiſt ſeparately without the vital and involuntary Actions: And this may probably ariſe, becauſe the Fibres of the Brain are in no Nerves extended without the Fibres of the Cerebellum, nor can we affirm that any one Nerve comes only either from the Brain or Cerebellum.

[2] All the Medulla of the Cerebellum is not ſpent in the ſpinal Medulla; for a conſiderable Part of the former aſcends forwards, and conjoins itſelf with

with the Fibres of the Cerebrum, as *Vieuſſens* and *Ridley* have obſerved; and this that they might be extended with the Fibres of the Nerves which ariſe from the Brain; ſo that the Nerves of the Medulla oblongata have their Origin in part from the Cerebellum as well as from the Brain.

3 It will readily appear to a conſiderate Enquirer, that ſo large a Body as the Medulla oblongata cou'd not ariſe from the medullary Fibres of the Brain only, without the Conjunction of the Fibres from the Cerebellum; even the whole annular Protuberance is compoſed of the medullary Fibres from the Brain and Cerebellum intermixed.

4 So that no one Nerve ariſes from the Medulla oblongata but what has Fibres both from the Brain and Cerebellum; nor is there any Point of the Medulla oblongata, nor of the ſpinal Medulla, in which there are not the Fibres of both interſperſed; if we except only the olfactory Nerves, which ſeem to ariſe from the Brain only: But it does not follow that theſe two Sorts of medullary Fibres are confounded indiſcriminately together becauſe they are intermixed; for tho' in their Diſtribution they are frequently interwoven and confounded in Plexus's and Expanſions like as the Cauda equina ſplits into an infinite Number of nervous Threads, like Hairs, without obſerving any regular Order in their Courſe, yet every Thread is very diſtinct from each other, and regularly diſpoſed from their Origin at the cortical Subſtance to their Expanſion in nervous Filaments.

Concerning the Juice or Spirit of the Brain and Nerves.

§. 274. WHoever then, with regard to the ſecretory Office of this Part, *conſiders* [1] (1.) the forementiond Nature or Fabric of the Cortex (§. 263 to 266.), with that of the diſtinct *medullary* [2] Fibres thence ariſing (§. 270.); (2.) the Similitude of this ſecretory Apparatus with that of all the other Glands in the Body; (3.) the vaſt Quantity of very thin, pure and fluid arterial *Blood* [3], ſo ſtrongly propell'd hither by the adjacent Heart, before it has loſt any of its more ſubtile Juices; (4.) the *very thin* [4] lymphatic Juice, which always appears within the medullary Subſtance of the Brain in Diſſections, manifeſt not only to the Touch and Taſte, but alſo to the Eye, eſpecially when armed with a Microſcope; and which Juice is often found in a much increaſed Quantity in moſt diſeaſed Brains; (5.) that the *Veins* [5] of the Pia Mater return the Blood from the cortical Subſtance of the Cerebrum and Cerebellum into the Sinus's of the Dura Mater, to be thence convey'd by the jugular Veins and Cava to the Heart; (6.) the conſtant, regular and proportionable Growth or *Increaſe* [6] and Nutrition of the Stamina or ſmall Threads of this Part, which are continually deſtroyed

deſtroyed and repaired from the firſt Beginning even to the Period of Life: Whoever conſiders theſe, muſt judge that the medullary Fibres are ſmall pervious Tubuli, receiving the moſt *ſubtile* [7] Juice of any in the whole Body; which being prepared and ſeparated in the wonderful Fabric of the Cortex, is thence propell'd from every Point thro' theſe Tubuli into the Medulla oblongata, and there collected.

[1] 'Tis true, we now aſſume an Argument which cannot be demonſtrated to our Senſes, ſince the moſt exquiſite Reſearcher into minute Objects, *Lewenhoec* himſelf, confeſſes that his Glaſſes could never make out to him the moſt minute Fabric of the Medulla; we muſt therefore have Recourſe in this Caſe to the Method we are often obliged to uſe in phyſical Matters, that is, by Reaſon and Analogy to trace the Structure or Fabric as a Cauſe *à poſteriori*, or from the obvious Phænomena and Effects; from theſe we are therefore to judge, whether the medullary Fibres (§. 270.) are either ſolid and impervious, or tubular, and ſo formed from a Number of ſmall Vaſcules, as to receive and convey a Liquor thro' their Cavity.

[2] We have before ſhow'd (§. 265.) that the firſt vaſcular Stratum of the Cortex, which is next to the Pia Mater, conſiſts of red or ſanguinous Veſſels, from whence ariſe the other Strata or Veſſels in the Cortex, which admit ſuch Juices only as are pellucid and thinner than the red Parts of the Blood itſelf; and we know that ſuch pellucid Veſſels as are ſeparately inviſible appear together of an aſh or grey Colour, like Flint Glaſs. We alſo know, that where the moſt ſubtile Part of this cortical Subſtance terminates, there the medullary

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Part apparently begins: But we have not any one Inſtance throughout the whole human Body of Veſſels terminating in a ſolid or blind Extremity (§. 132. N° 20.); but open either into other Veſſels or into ſome Space or Cavity; otherwiſe the Circulation of our animal Juices would ceaſe: 'Tis therefore hence probable, that as the ſmaller pellucid Veſſels ariſe from the ſanguiferous or red Vaſcules of the Cortex; ſo from the ſmalleſt Series of pellucid Vaſcules in the Cortex ariſe the very minute Tubuli of the Medulla. How prepoſterous and unparallel'd wou'd it be to aſſert, that the Blood and its moſt ſubtile Juices are convey'd to ſolid and impervious Fibres in the Medulla, and then returned again by the Veins without performing any thing but its Circuit; this wou'd be not only repugnant to the wiſe Oeconomy of Nature, but alſo refuted by the Inſtance of all the other Viſcera, eſpecially the Kidneys, where the ſecretory Tubuli ariſing from the cortical Fabric bears ſome Analogy to this Part; and if it be ſaid that in the Spleen the Blood paſſes without performing any thing there beſides its Circuit, we anſwer, that there we have no Appearance of any ſecretory Tubuli, but only a Congeries of Veſſels.

3 *Malpighi* ſhows how vaſt a Quantity of Blood is impell'd to the Brain (§. 239.), which at leaſt receives more than any other Viſcus; nor is the Brain ever deprived of its great Quantity of Blood, even in tabid or conſumptive Patients whoſe Bones are viſible thro' their Skin; for in ſuch we obſerve the Cranium quite full, and the Brain as large and as ſound as ever. I can hardly believe any one will entertain a Notion ſo abſurd, as to think that all this vaſt Quantity of Blood is ſent to the Brain for nothing, as it muſt be if there is no Secretion there made from it; for if the Blood was only ſent

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by the Arteries to the Brain, and again return'd as it went by the Veins, all this vaſt Quantity of Blood, amounting to near one third of the whole Maſs, would be in a manner loſt, and take this Courſe for no Uſe either to itſelf or the Brain.

4 I have frequently obſerved that by dividing the Medulla oblongata with a very ſharp Razor, and then inſpecting with a Microſcope, there appears little Drops of Moiſture tranſuding like Dew, which preſently exhale and dry up, or if you wipe or ſcrape them off, they are preſently again renew'd. If a Brain be diſtill'd with a very ſlow Fire, or a Heat not exceeding that of boiling Water, it quickly turns almoſt wholly into a lympid Water, leaving very few ſolid Veſſels behind. The Liquor found in the Ventricles of the Brain in a healthy Man that has died a violent Death, wholly evaporates with Heat, as *Bellini* obſerves; and the Subſtance of the Brain itſelf, freed from the Pia-Mater, almoſt wholly evaporates in the Shade; but it is not probable that the Veſſels themſelves evaporate, only the ſmall Veſſels having exhaled their Liquors collapſe and ſhrink up to a Membrane. This Liquor of the Ventricles is alſo frequently obſerved in great Plenty after lethargic Diſorders of the Brain, which has been taken Notice of even by the Ancients, who therefore pronounced a moiſt Brain to be attended with dull Intellects.

3 Where-ever the Blood is driven into a Part by Arteries, and returned again by Veins, there is always ſome Secretion made from it; nor is there any Reaſon to be offer'd, why ſuch a Secretion ſhou'd not be performed in the Brain.

6 This is an Argument next to a Demonſtration: For in the human Animalcule, leſs than a Grain of Sand, and in the incipient Fœtus, no bigger than

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an Ant, there is both a Brain, Cerebellum, and ſpinal Marrow; all which grow and increaſe in Proportion with the reſt of the Body: Suppoſing then that the Brain and its Appendages are augmented and nouriſhed like the reſt of the Body, that is, by an uniform and equable Diſtention of Parts, by the Juices propell'd thro' the Arteries by the Force of the Heart; the ſame Cauſes muſt be then admitted in the Brain, *viz.* a Supply of Juices from the Heart to every individual and minuteſt Fibre, of the Medulla as well as the Cortex; or elſe how does the firſt grow and increaſe if it be only ſolid Fibres, having no Commerce with the Arteriolæ of the Carotids. I therefore conclude for my own Part, that this Argument is little inferior to an ocular Demonſtration; nor can any Objection of Conſequence be raiſed againſt it; even the Minuteneſs of the Vaſcules rendering them inviſible is of no Force againſt us.

7 The great Tenuity of this Juice is apparent from the Experiments of *Ruyſch*, by which he cou'd never inject the ſmaller Arteries from whence it is ſeparated; for when I have been preſent with this celebrated Anatomiſt about to inject, he has declared to me before-hand, that he cou'd not promiſe his Injection wou'd ſucceed equally alike, but ſometimes one Part happen'd to take well, and ſometimes another: And in the fulleſt Injection he ever made of the Brain, the Arteries of the whole Pia Mater were diſtended, and ſome ſmall Part of the Cortex next the Pia Mater look'd red; whence the ſmaller Veſſels next continuous to the red injected ones were diſſolved when he compleated his Preparation by macerating in Water, in order to ſuſpend it in Spirit of Wine. And it is evident that many of the Veſſels in the Cortex were fill'd by his Injection with a much greater Force than is ever exerted

exerted naturally, ſince no Part of the Cortex ever appears red without Injection; and therefore the ſmalleſt of the injected Veſſels in his Preparation were naturally pellucid or ſerous, and not ſanguiferous Arteries: In the ſame manner too we obſerve but very few ſanguiferous Arteriolæ creeping on the Albuginea of the Eye, when it is not inflamed; but in Ophthalmias and the Preparations of that Tunic by *Ruyſch*, it appears all over red, by Blood or Injection being forced from the ſanguiferous into the firſt, and perhaps the ſecond Series of lymphatic Arteriolæ thence ariſing; but the greateſt Part of the Cortex, which is only many Strata of Vaſcules, we ſee cannot be injected; and therefore it follows that the Cortex muſt contain many more Series of lymphatic Arteriolæ ſtill ſmaller than the firſt and ſecond Order, which cannot be enter'd or injected by the moſt ſubtile coloured Liquor.

§. 275. And if, with regard to the Nature of this Juice, we again conſider (1.) the particular State or Diſpoſition of the Blood brought to the Brain by the carotid and vertebral Arteries (*per* §. 224 and 235.), by which it differs from all the other Blood in the whole Maſs; (2.) the moſt ſubtile or minute Structure of the evaneſcent Arteriolæ, coming from the Vertebrals and Carotids, vaniſhing in a ſort of downey or cotton-like Pulp, and by an inſcrutable Implication and Contexture forming the Subſtance of the Cortex (§. 236.); (3.) the particular Nature of that Juice (§. 274. N°. 4.) which ſo ſuddenly exhales of its own Accord, and does not harden with Heat as do the lym-

phatic Juices, and which ſo nearly evaporates as to leave little or no Reſiduum; (4.) the great Power and *Celerity* [1] with which we daily obſerve this Fluid act in the Nerves and Muſcles: Whoever conſiders theſe and the preceding Circumſtances (§. 274.) will readily conclude the component Particles of this Juice are the moſt ſimple, *denſe or firm* [2], ſubtile and *moveable* [3] of any Juice throughout the whole Body.

[1] I no ſooner will the Extenſion of my Arm, but the Action inſtantly follows without any ſenſible Interval: But this Action of the Mind muſt be firſt exerted in the Brain, notwithſtanding M. *Perrault*'s Opinion to the contrary. We are furniſhed with innumerable Experiments which argue againſt him, and demonſtrate that the Brain being obſtructed or deſtroyed, the voluntary Motions are thence ſuppreſſed; and that by intercepting the Commerce betwixt the Brain and any Part, that Part immediately ceaſes to be governed and actuated by the Mind. But if the muſcular Motion of a Part ſo immediately follows the determinate Action in the Brain, it is evident that no Juice can ſuffice for the Office, but what is apt to move the ſwifteſt and eaſieſt of any.

[2] Tho' the nervous Juice or Spirits ſeparated in the Brain are the moſt ſubtile and moveable of any Humour throughout the whole Body, yet are they formed like the reſt from the ſame thicker Fluid the Blood, paſſing thro' many Degrees of Attenuation, till its Parts become ſmall enough to pervade the laſt Series of Veſſels in the Cortex, and then it becomes the ſubtile Fluid of the Brain and Nerves. But as far as we can perceive, all the circulating

Juices

Juices in the Body conſiſt of ſpherical Particles, and therefore this circulating Juice of the Nerves probably conſiſts of ſuch figured Particles, only ſimple, or the leaſt compounded of other ſmaller Spherules of any Humour in the whole Body; and therefore ſuch ſimple or leaſt compounded Spherules will be the moſt ſolid, or the leaſt apt to divide and break into leſs. They will be more denſe, ſolid and permanent, as being ſimple Spherules; whereas the other larger Spherules, compounded of ſeveral ſmaller, intercept Pores, and are thence lighter, more diviſible and unactive. Thus Gold, whoſe elementary and conſtituent Particles are altogether ſimilar and very compact, is a moſt durable or permanent Body, not capable of being deſtroyed even by the intenſeſt Fire.

[3] They will be the moſt fluid or moveable of any Particles, as having no Tenacity or Viſcid Coheſion to each other, by which they will very often change their Contacts by the leaſt Force; otherwiſe they wou'd never exhale ſo readily *(per* §. 264.)

§. 276. But the red Parts of the Blood appear by the Microſcope to be the groſſeſt or *largeſt* [1] of all that are contained in any of our healthy Juices; and in the mean time the Serum, conſiſting of Particles much ſmaller than the red Cruor, is ſubdiviſible into Corpuſcles or Spherules incredibly leſs than any we can obſerve in it, as may appear from the Increaſe of the Fœtus or *Carina in Ovo* during Incubation, where the Albumen, which is thicker than the Serum, is ſucceſſively ſo attenuated, that it at length becomes capable of pervading all the inconceivably ſmall Veſſels in the little

Embryo: Even the leaſt Inſect in the World has its infinitely numerous and different Veſſels, pervaded by their reſpective Juices, not excepting thoſe infinitely ſmall Animalcules diſcernible with good Glaſſes in the Semen maſculinum; from all which it is evident that the Particles of this very ſubtile Juice, or Spirit of the Brain and Nerves, are to be eſteemed vaſtly ſmaller than they are generally imagined to be.

[1] Truſting to Reaſon and Experiment to conduct us in our preſent dark Enquiry, I ſhall endeavour to ſhow you by a familiar Inſtance, how a groſs Liquor may afford a very ſubtile one barely by Heat and Attrition. We know by *Lewenhoec*'s Obſervations (§. 226.) that each red Globule is compounded of ſix ſmaller ſerous ones, into which they diſſolve or ſeparate by a gentle Heat. Now this ſame Serum into which the Cruor is reſolvable, does by the Heat of ſcalding Water concrete like the White of a boiled Egg; but being digeſted with a very gentle Heat, only equal to that of a healthy human Body, it diſſolves or turns to a very thin and pellucid Serum almoſt like Water. In the Egg which weighs about two Ounces, under a ſitting Hen, various Juices are contained within the Shell, the Calaza or white Ligaments, Albumen, Yolk, and Cicatricula; which laſt is a little whitiſh Sacculus, about the Size of a ſmall white Pepper-corn, and full of a very lympid Liquor, in the midſt of which is lodged a white Spec no bigger than the Head of a minikin Pin, and of a very high Reliſh or Taſte. The Egg fill'd with theſe ſeveral Juices, and placed under the ſitting Hen, is found to have diminiſh-

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ed in its Albumen upon opening it on the third Day after Incubation; while the Cicatricula or little Sacculus of Colliquamentum is at the ſame time proportionably larger, and the Spec or Point in it has a viſible Pulſation, and is enlarged into the Form of a Vermicle: Alſo if you break an Egg at long Intervals after Incubation, the Albumen will always be found proportionable leſs or more diminiſhed as it has been longer ſit upon, and the Carina or incipient Chick with the Amnios or including Membrane appears ſo much the more enlarged. Laſtly, if you break an Egg on the twentieth Day after Incubation, there will be found little or none of the Albumen in the including Shell and Membranes; while the Yolk at the ſame time appears to have undergone little or no Alteration, but the Sacculus or Amnios is ſurpriſingly diſtended, and contains the Carina or Chick ſo much augmented, that itſelf weighs near the whole two Ounces of the Egg. Hence it manifeſtly appears, that the Albumen only is the Matter from whence the whole Body of the Chick is formed in the Space of twenty-one Days: But this Albumen is a gelatinous Liquor included in concenteric fine Membranes or Lamellæ, continually leſſening and refining in Texture towards the Center, like Coats of an Onion, the Yolk itſelf and the Colliquamentum or Carina being the Center of thoſe Lamellæ. Theſe Liquors of the Egg quickly putrefy if it be not prolific, and becoming volatilized exhale thro' the Pores of the Shell and including Membranes; nor will they then harden with Heat like as in a ſound Egg, which affords a certain diſtinguiſhing Sign to detect an addled or unſound Egg. But if the Egg was fecundated by the Cock, and then retained in a gentle Heat, then the thick Albumen is ſucceſſively attenuated from one Lamellæ to ano-

ther, and being elaborated in the ſmall Glands of the Yolk is at length convey'd by the omphalo-meſenteric Veſſels of *du Verney* into the Inteſtines and Veins of the incipient Chick; and is laſtly converted into its ſeveral vital Juices, pervading even the Brain and Nerves in Form of ſuch a fine Liquor as will not harden, but eaſily exhale in Vapours. In the ſame manner the Serum of the Blood (which is ſo much of the ſame Nature with the Albumen, having the like Tenacity, and hardening with Heat) is gradually ſo attenuated by the perpetual Attrition given to it by the Arteries, that by paſſing thro' various Degrees of Tenuity, it at length loſes its Tenacity, and becomes a moſt ſubtile, moveable, and volatile Liquor, pervading thro' the cortical Part of the Brain, which admits none of the red Blood (*per* §. 235.): And it is not improbable but that the ſeveral Strata of decreaſing Veſſels in the Cortex may be concentric, and analogous to the ſeveral Lamellæ of the Albumen in the Egg.

§. 277. From what has been ſaid we may alſo affirm that this Juice is of a very different Nature from any *ſaline* [1] Subſtance whatever, whether produced by Art or Nature; becauſe we obſerve that all the Properties or Affections of the ſaid Juice are vaſtly foreign to all thoſe of ſaline Subſtances: And much leſs can it be formed of any *oily* [2] Matter hitherto known; ſince ſuch Subſtances are injurious to the Tubuli or hollow Fibres contained in this Juice. Nor has it any Reſemblance to the *Spirits* [3] produced from vegetable Matters by Fermentation; becauſe thoſe Spirits, in their pureſt State,

State, first shrink and dry up the Fibres or Tubuli, and then render them unfit to perform their Offices. 'Tis rather more probable, that this Juice or Spirit of the Brain and Nerves is like those of the most subtile and pure Water, from their agreeing so nearly in the Solidity, Smoothness, Simplicity and great Fluidity, or Disposition for moving, and their want of Elasticity; notwithstanding we are assured that they arise from other Materials than Water, as appears from the Transmutation of the Juices in an *Egg*[4] by Incubation.

[1] Whether acid or alcaline; notwithstanding the Chemists teach that the Spirit or Juice of the Brain is composed of volatile Salts much more penetrating than Water; because, say they, such Salts arise from the Blood and Juices when exposed to a Heat the same with that of a healthy Body which comes near to the Heat of a sitting Hen; *M. Paschal*, and others, again suppose them acid, and Dr. *Mayow* thinks them like to the aereal Nitre; but 'tis notoriously obvious to every one, that the Substance of the Brain has naturally no Taste or other Property belonging to Salts; on the contrary, there is not any one Part in the whole Animal more insipid, insomuch that it is scarce eatable without a great deal of acid, Sea-salt, or other Sauces; or were the Tubuli of the Brain and small Vascules of the Cortex to be pervaded in their natural State, by such acrid saline Juices they would be totally dissolved together with the Medulla of the Brain and the Substance of the Nerves themselves; nor could saline Particles pass through such minute Tubuli, which are too small to admit even the Parts of Water itself.

2 *Willis* ſuppoſes the Medulla of the Brain to be of an oily or ſulphurious Nature, a Property the remoteſt of any from the Nature of this Juice, which if it were like Oil would be too enacious to enter ſuch minute Paſſages and move ſo ſwiftly as we often obſerve in the Muſcles, *&c.* *F. Redi* obſerved that Serpents and Fiſh included in a cloſe Veſſel turned into a fætid Liquor, like a pellucid Water, with ſome Oil ſwimming on the Top, from the Fat of the cellular Membrane under the Skin, *&c.* which ſhews that animal Juices are not of a ſulphurious Nature.

3 This Hypotheſis, which we are going to refute, has pleaſed many celebrated Phyſicians, and ſome who have profeſſed in the preſent Chair of *Leyden*; where it has been taught that a Catalepſy is Congelation of the animal Spirits by a volatile alcaline Salt, in the ſame manner as Alcohol Vini and Spirit of Sal Ammoniacum do upon Mixture run into the ſolid Offa Helmontiana. There are indeed many ways of refuting this Opinion: For neither is there any Fermentation in the human Body whereby to generate a vinous Spirit from an acid or vegetable Juice, nor is there any Fire and Apparatus in the ſame to diſtil and ſeparate ſuch a volatile, oily, and inflammable Spirit; nor could it, if it was ſeparated, pervade the ſmall Tubuli of the Brain and Nerves, ſince it in a great meaſure partakes of the Tenacity of Oil, as appears from its running down the Sides of a Glaſs in Striæ; and ſince by its ſtrong Attraction of Water or conſtringing Quality, whereby it preſerves anatomical Preparations, it wou'd indurate and cloſe all the Veſſels and Paſſages. Nor does the Juice of the Brain manifeſt any phlogiſtic Quality, but extinguiſhes a Flame when thrown upon it; nor can it reſiſt being

ing frozen by the moſt intenſe Froſt, as Alcohol will.

4 The Matter from whence the Juice or Spirits of the Brain are prepared, is the Viſcid and tenacious Serum of the Blood, which by paſſing thro' many Degrees of Attenuation, at length acquires the Subtility of a Spirit, after its Particles have been moulded or formed by paſſing frequently thro' the ſmalleſt Series of Veſſels in the Body; paſſing from Blood into Serum, from Serum into Lymph, and from Lymph of the firſt Order in all ſucceſſive ſmaller ones, till at laſt loſing the Nature of Lymph it acquires the ſubtile one of a Spirit. But as the Albumen of the Egg is ſo much like the Serum of the Blood, and the Heat of the human Body ſo near to that of a ſitting Hen; we ſhall, perhaps, not judge amiſs if by Analogy we reckon the Time required to prepare one Juice by the other; *i. e.* as the Albumen takes twenty-one Days time to turn it rotten or elſe digeſt it into the healthy Juices of the Chick, ſo the Serum of the Blood may take about the ſame time to digeſt and break it ſmall enough for this Juice of the Brain; for ſimilar Cauſes generally yield ſimilar Effects. This Juice is therefore not a mere Water, for that wou'd be too rigid, and its Parts would have none of that mild Tenacity neceſſary for their adhering to the healthy Fibres for Nutrition; nor is Water a Cordial, but thoſe Liquors only are Cordials, which are either themſelves apt to turn into good Blood, or which ſo augment the Powers of Life, as to convert the Blood into nervous Fluid by making it paſs through all the ſeveral Degrees of Attenuation. Too plentiful drinking of watery Liquors and Water only are ſo far from recruiting the Spirits, that, after a ſhort Flow of Spirits, they infringe and weaken all the vital Powers. A Redundancy

dundancy of Water is the frequent Cauſe and Companion of Lethargies; and yet, notwithſtanding, the Nature of the nervous Juice is not very remote from that of Water; for if the whole Brain be diſtill'd with a Heat equal to that of boiling Water, it affords the greateſt Plenty of that Liquor, differing little or nothing from ſimple or pure Water; though by a ſtronger Heat you may alſo obtain the ſame Salts, Oils, *&c.* as from the Blood (*per* §. 227. N° 2.)

§. 278. We are again convinced that the Quantity of this Juice muſt be very *large* [1], and be perpetually renew'd or made afreſh every Moment while we are alive and well; as may appear from conſidering the Magnitude or Size of the carotid and vertebral Arteries; from their direct and ready Courſe to the Head, free of all Impediments; from the vaſt Quantity of Blood impell'd through them by the Heart; from the greater Velocity with which it arrives, and from the vaſt Quantity or Extent of the cortical Subſtance, all which ſufficiently prove the Largeneſs of the Secretion.

[1] If we examine the Brain and its Appendages, to wit, the Cerebellum, Medulla Oblongata, and Spinalis, we ſhall find no other Viſcus ſo large in the whole Body; and if to that Conſideration we add the great Quantity, Velocity, and direct Courſe of the Blood ſent thither by the very adjacent Heart, and that this Blood is more refined and repleniſhed with ſpirituous or eaſily moving ſmall Particles than any other Blood of the whole Maſs,

Maſs, we may then readily conclude that this Juice is prepared very copiouſly and powerfully.

§ 279. And ſince the Office of this tender Apparatus is ſo important, therefore the whole Encephalon is included and defended in a Caſe of reſiſting *Bones* [1], without being loaded or preſſed by any incumbent *Fat* [2], Muſcles or other Bodies; and as its Arteries and Sinus's are alſo equally ſecured from ſuch Incumberances in their Courſe, keeping always the ſame State or Diameter, it follows from the whole, that this Juice will be *equally* [3] and uniformly prepared in the ſaid Viſcus.

[1] No leſs ſurpriſingly than advantageouſly framed of eight diſtinct Bones, of different Figures, ſo connected as to give way and yield to the Extenſion and Growth of the Inhabitant, which is thus ſecured from Injuries and Compreſſure.

[2] There are indeed ſome few Inſtances of Fat being obſerved about the Brain, but never without fatal Conſequences, as you may ſee in *Bonneti Sepulchret. Anat.*

[3] We have before obſerved, that the Brain is not liable to that Stimulus or Preſſure of the Muſcles, which increaſes many Secretions more at one time than at another; nor does it waſte or fail of its juſt ſupplies from the Heart, even in the laſt Extremity of a Conſumption, where a little before Death the Patient's Senſes are in great Perfection; and after, the Cranium appears full, and the Brain perfectly entire: And thus I remember a little Girl who was ſo waſted in an Atrophy, that all the Blood-veſſels quite vaniſhed, and ſhe had not the

the Power of moving any Limb, and yet her Senſes continued entire even to the very Article of Death.

Of the Nerves.

§. 280. IN the next Place the Medulla *oblongata* [1] and ſpinalis, (inveſted with a very thin Membrane compoſed of exceeding minute Veſſels, diſcover'd by the *Ruyſchian* Art of injecting, and conſiſting of the medullary Fibres of the Brain and Cerebellum collected together) ſent forth within the Skull, in twenty different places, *ten* [2], falſely call'd, Pair of Nerves, ſince moſt of them conſiſt in reality of ſeveral diſtinct and large Nerves joined together; but from the ſpinal Medulla without the Cranium ariſe in the ſame manner *thirty* [3] Pair of Nerves, which are, like the former, very much compounded of other leſſer ones; beſides one Pair of Nerves ariſing out of the Cavity of the Spine or Vertebræ of the Neck, near the fourth Pair of vertebral Nerves; and uniting in its Aſcent with Branches from the ſecond and third Pair, it thereby becomes gradually thicker and larger, till it at laſt joins with the eighth Pair of Nerves.

[1] The cortical Part of the Brain receives the moſt ſubtile and pellucid, rejecting the red Parts of the Blood from the Pia Mater; which more ſubtile Parts

Parts of the Blood pass successively thro' the several smaller Series of Vessels in the Cortex, till being highly attenuated, it at length enters the medullary Tubuli: But the Fibres of the Medulla are all collected into that of the Oblongata, and then sends forth Nerves, which never arise separately either from the Medulla or Cortex of the Brain alone, but from the Medulla oblongata and spinalis, formed by the Conjunction of the Medulla of the Brain and Cerebellum together.

[2] Rather nine Pair, the last of which belong to the Tongue; for the tenth is an accessory Pair, arising from the Medulla spinalis, and entering within the Cranium, it joins with the eighth Pair of the Brain, and then returns out of the Cranium again.

[3] The spinal Nerves strike off nearer from their Origin or Medulla in the Case of Vertebræ, than those which come from the Medulla oblongata within the Cranium. The last Extremity or Termination of the Brain is near the Os sacrum, in a numerous Assemblage or Bunch of nervous Filaments, termed from its Appearance, the *Cauda equina*.

§. 281. All these Nerves, while concealed within their medullary Substance, are of a soft and pulpy Consistence; but passing out from the Medulla they are cover'd with an *Integument* [1] from the Pia Mater, wherein they are secured as they proceed, and then perforate the *Dura Mater* [2], which is extended round them in canular Productions like a Sheath, reaching as far as the Foramina of the Cranium thro' which the Nerves pass, where the

the Integument of the Dura Mater unites with that of the Pia Mater; and closely investing the nine Pair of Nerves with the accessory Pair, secures them wonderfully in their Progress from the Cranium: but the other thirty-one Pair of spinal Nerves descend downwards thro' the broad and artful Spaces formed betwixt the Margins of each vertebral Apophysis; from whence emerging, they are immediately after secured by their Integuments, and becoming firm and compact are dispersed thro' every individual Point of all the several solid Parts of the Body with which we are yet acquainted.

[1] The Consistence of the Nerves, as they arise in the Brain, is very soft and medullary; but having reached the Margin of the Medulla oblongata from whence they emerge, they first receive an Integument or Coat there from the Pia Mater, as is generally said by Anatomists; but the optic Nerve has its medullary Substance apparently invested with an Integument much harder than can be well derived from that Membrane; nor does the said Tunic perform the Office of the Pia Mater, since none of the Nerves are furnished by the cortical Substance or Fabric. Upon this last Tunic, immediately investing the medullary Substance of the Nerve, is spread the Tunica Arachnoides, and cellular Membrane, thro' which the small Vessels are distributed on the Surface of all the Nerves.

[2] The Dura Mater not only invests the whole Surface of the Cranium internally, but is also extended without, over all the Nerves which pass from the Cranium, and accompanies them even in their Distributions. I examined the spinal Medulla after

it

it had been with much Labour freed from its Caſe of Bones, from the Occiput to the Cocyx, by an indefatigable Anatomiſt, and cou'd then ſee many Fibres of the Medulla deſcend and run together into a Bundle forming one Nerve, which paſſed out thro' a Foramen of the Dura Mater, which gives a very ſtrong and hard Coat to the Nerves, which after they are gone ſome way from the Spine, join together in Ganglia, or Knots of a hard, fleſhy, or cartilaginous Texture; but the medullary Part of the Nerve continues of as ſoft and mucous a Subſtance in the ſmalleſt Fibrils, as at its Origin in the Brain itſelf. Thus the optic Nerve taken together ſeems tough and hard, but on dividing it tranſverſly, the mucous medullary Subſtance is forced out from its containing Integuments by their natural Contraction; but there is no Neceſſity for you to divide or wound the Nerve to be convinced of its Medulla; for by tracing it a little farther from the Cranium, it puts off the hard Integument received from the Dura Mater, and therewith forms the Sclerotica or hard Coat confining the whole Globe of the Eye; it then alſo depoſits the inner Coat, received from the Pia Mater and Tunica Arachnoidea, which forms the Choroides of the Eye next to the Sclerotica; ſo that theſe Membranes being depoſited from the Nerve, it is now expanded in a ſoft medullary Plexus termed the Retina. The ſame is alſo true of the auditory Nerve, which depoſits the two Integuments it received from the Dura Mater, within the auditory Sinus; and that from the Pia Mater is thrown off upon the Tympanum, while itſelf continues expanded in the Cochlea and ſemicircular Canals a mere Mucus or Medulla: Whence it is manifeſt, that the callous Hardneſs of the Nerves ariſes from their including Membranes, in which the Medulla

from

from the Brain retains its original Diſpoſition without any Change throughout their whole Diſtribution to every Point of the Body. So that which is ſhow'd in anatomical Demonſtrations under the Name of a Nerve, is a ſmall Portion of the medullary Subſtance included in tough Membranes.

§. 282. But theſe Coats of the Nerves (§. 281.), are every where ſpread with ſmall *ſanguiferous* [1], lymphatic, and other Veſſels, inveſting their whole Fabric very cloſely; ſo that they do not conſtitute this Part as a Nerve, but only ſerve to collect, ſecure and convey the medullary Fibrills or Tubuli to their reſpective Parts; from conſidering which, you may account for many Phænomena and Diſeaſes of the Nerves.

[1] My Friend *Ruyſch* writes in an Epiſtle to me, that his Injection ſucceeds the moſt beautifully when forced in by the umbilical Veſſels of a Calf that has been lately dropp'd: For then even the Integumeuts of the Nerves appear beautifully painted with Blood-veſſels. In the optic Nerve we obſerve four little Arteries running externally in its hard Integument, without entering its medullary Subſtance, ſince they belong only to the Membranes: But the Medulla of the Nerve has an Artery running thro' its Axis or Center, and expanding itſelf laterally with the Retina, and cauſes a blind or inſenſible Point in the Center of the Retina. There are an infinite Number of ſanguiferous Veſſels diſtributed in the Dura Mater and its Membranes, and there are doubtleſs Lymphatics alſo of the ſeveral ſmaller Series: All which Veſſels, even thoſe of the Brain and Nerves, are inveſted with the cellular Membrane;

Membrane; and therefore here ſeems to be the Seat of many nervous Diſorders which are independent of the Brain, ſuch as one Species of the Rheumatiſm and Gout, tho' the former is generally ſeated in the vaſcular Plexus's of the Membranes, Tendons and Muſcles; and the Species of the Gout which I mean, is that termed by *Hippocrates* the profound Separation of the Blood, *&c.* which Diſorders, as alſo Palſies of the Joints, where the Brain is unaffected, may be removed by topical Remedies, as I have myſelf experienced; which can hardly be expected, when the Seat of the Diſorder is in the Medulla or Brain, ſuch as Palſies following Apoplexies, Lethargies, *&c.* which are never curable without reſtoring the Brain to its former Integrity.

§ 283. But when the ultimate Fibres of theſe Nerves enter the Parts to which they are determined, they then depoſit the *Coats* [1] they before received from the Meninges, and are ſoon after expanded in Form of a very thin and tender Membrane, or elſe end in a ſoft Pulp.

[1] We have already obſerved this of the optic and auditory Nerves (§. 281. N°. 2.); and it is the ſame with the olfactory Nerves, which approaching the Os cribroſum paſs thro' the little Sheaths or tubular Productions of the Dura Mater, and then expand like a ſoft Pulp on the Membranes of the Noſe, giving way to the leaſt Preſſure like a Mucus. The ſmall tactile Nerves are demonſtrated by *Malpighi* and *Ruyſch* to be very ſtrong and hard till they reach the reticular Body of the firſt, under the Cuticle, where they depoſit their Integu-

ments of the Dura and Pia Mater, the laſt forming the Corpus reticulare *Malpighii*, and the former the Cuticle, while the pulpy Subſtance of the Nerves themſelves is formed into little Heaps termed Papillæ; and if you remove the ſaid Cuticle and reticular Body, there appears underneath them a Congeries of naked, ſoft, gelatinous and very ſenſible Papillæ in the true Skin. If powder'd Cantharides are applied to any Part of the Skin, and ſuffer'd to remain too long on the Part, as I have ſometimes known, and then a ſtrong Baſilicon-Plaiſter impoſed over the naked Papillæ, after the Cuticle has been elevated and the Papillæ much corroded by the Acrimony of the Flies, it excites ſuch an excruciating Pain in the ſaid Papillæ, which are then eaſily diſcernible by the Microſcope, that Convulſions and even Death itſelf have been known to follow. And the ſame direful Symptoms will alſo follow upon an ignorant Surgeon's ſcraping off the ſaid nervous Mucus or Papillæ appearing under the dead or deſtroyed Cuticle. All the Nerves therefore in the Body terminate one and the ſame way, nor is the leaſt Fibre or ſolid Part of the Body without its Nerve, or which is not as well ſupplied with the nervous as with the arterious Syſtem.

§. 284. If we therefore attentively *conſider* [1], (1.) that the medullary Subſtance (§. 270, 274.) wholly pervious or tubular, is entirely ſpent in compoſing the ſmall Fibres of the Nerves, paſſing into them alone in one continued Courſe without any Interruption; (2.) that if the Medulla of the Cerebrum or Cerebellum be *compreſſed* [2], wounded, putrefied or eroded, all the Actions of the Nerves thence ariſing are immediately aboliſhed or deſtroyed, notwithſtanding

ſtanding the Nerves themſelves and their Integuments are entire and without Injury; (3.) that all the Nerves very readily perform their Office, tho' they are every-where either lax or pendulous, and diſpoſed either in oblique, *crooked*[3] and inflected or retrograde Courſes; (4) that the Nerves being compreſſed or tied, even without wounding 'em, the Parts to which they belong, betwixt the Ligature and *Extremity*[4], loſe all their Faculties of Senſe and Motion, while thoſe Parts which are ſupplied by the ſame Nerve betwixt the Ligature and Medulla of the Brain are unaffected; whoever reflects on theſe Circumſtances will readily conclude, that thoſe Fibres or Tubuli of the Nerves continually *receive*[5] the Juice of the Medulla (§ 275 to 278.), and tranſmit the ſame by very diſtinct Paſſages to every individual Point of the whole Body, and that by the Conveyance of this Juice only they perform all their Actions and Uſes as Nerves.

[1] There are two Opinions which at preſent prevail with regard to the Nerves, ſome thinking them pervious and filled with a kind of Juice ſubſervient to Senſation and muſcular Motion, which is one Opinion; others ſuppoſe them ſtretch'd from their Origin like tenſe and ſolid Chords, conveying the Impreſſions of Objects to the Senſorium, and performing the Motion of the Muſcles by mere Vibrations.

[2] There was a Man at *Paris* who at times begg'd Money in a Piece of his own Skull, his Brain being only cover'd with the Dura Mater; and he would frequently permit Experiments to be made

for a ſmall trifle of Money. Upon gently preſſing the Dura Mater with one's Finger, he ſuddenly perceiv'd, as it were, a thouſand Sparks before his Eyes; and upon preſſing a little more forcibly, his Eyes loſt all their Sight; by preſſing the Hand ſtill ſtronger on the Dura Mater, he fell down in a deep Sleep, which was attended with all the Symptoms of a ſlight Apoplexy, merely by this Preſſure with the Hand; which was no ſooner remov'd, but he as gradually recover'd from the Symptoms as they were brought on, the apoplectic Symptoms firſt vaniſhing, then the Lethargy, and laſtly the Blindneſs, all his Senſes recovering their former Perfection. This is a manifeſt Argument, that the Source of Motion and Senſation is in or dependent on the Brain, which being free and unaffected they are alſo in the like manner duly exerciſed, but by any Diſcompoſure of the Brain they are proportionably impaired or aboliſhed. If a ſmall Artery is ruptur'd within the Cranium of the moſt healthy Perſon, by the Efflux of an Ounce or two of Blood from thence, the internal Parts of the Brain and Medulla will be compreſſed, and the Patient will perceive, firſt, a kind of red Atmoſphere or Vapours about his Eyes; after which every thing will ſeem to turn round, and he will at laſt fall down apoplectic, deſtitute of all the animal Faculties, and without Senſation or any voluntary Motions; but as in this Caſe there is no other Change made in the Brain and Nerves but a Compreſſure of their Origin, it is thence evident that they muſt of neceſſity be pervious to ſome Fluid, which being thus obſtructed cauſes all the forementiond Symptoms.

3 All the Nerves paſs out of the cranium with a conſiderable Incurvation; but the nerves of the Heart, on whoſe Motion depend all the Actions

of

of the human Machine, run in a ſtraight Courſe betwixt the Aorta and pulmonary Artery; the recurrent Nerve particularly is inflected round the ſubclavian Artery, and then returns upwards out of the Thorax. *Lower* obſerves, that the ſpinal Nerves deſcend from the Medulla, and after they have made ſome Progreſs they are again reflected upwards; but notwithſtanding all theſe Incurvations and Inflections, we ſee that the Nerves continually move the Parts, and perform their ſeveral Offices; which they cou'd not do, if they acted in the manner of tenſe Chords; for to perform muſical Oſcillations or Tremors, the Chords muſt be ſtretch'd in right Lines without touching other Bodies, otherwiſe their impulſe will not be duly propagated.

4 Formerly *Galen*, and latterly *Bellini*, have made curious Experiments with Ligatures upon the Nerv s of Brute Animals; from whence it appears, that if the crural Nerve of a Dog be denudated, and then tied with a broad Ligature or Piece of Tape to avoid cutting the Nerve, all the Senſe and Motion of the Part below the Ligature to which the Nerve belongs, is ſoon after deſtroyed; nor will the Senſe and Motion return again after the Ligature is remov'd, without the Nerve be treated with warm Applications: The Nerve is not therefore a tenſe Chord, for that will give a Sound, tho' a falſe one, tho' you make the ſtricteſt Ligature on it. But you may make the ſame Experiment with much more eaſe in your own Perſon, without the Trouble of repeating it in the manner before deſcribed on a living Brute; for if, as you ſit, the Ham of one Leg be laid over the Knee of the other, by continuing in that Poſture for ſome time, and compreſſing the Nerve, you will no ſooner attempt to riſe up, but a Numbneſs or paralytic

ralytic Diſorder is perceived in the Limb, which has a painful Senſation, popularly known by the Name of one's Foot being aſleep, which Symptom gradually vaniſhes in a little time after the Nerve is ſet at Liberty from the Preſſure.

[5] So that every Moment a Perſon is alive and well, the Blood is impell'd from the Heart to the Cortex of the Brain, and its thinner Juices being attenuated in their Paſſage thro' the ſeveral Series of the Veſſels in the cortical Fabric, are at laſt tranſmitted in the Form of a moſt ſubtile Liquor into the medullary Tubuli; from whence it paſſes in an uninterrupted Courſe into every individual Part of the Body by the Nerves. To corroborate this Doctrine, we may add the experiment of *Drelincourt*, who having made a Ligature upon the carotid Arteries of a Dog, he fell down ſuddenly apoplectic, nor had he any Senſation without relaxing the Ligature. I am ſenſible that this Syſtem is oppos'd by ſeveral ſpecious Arguments and Difficulties urg'd by thoſe who deny the Exiſtence of a nervous Juice; but I am fully perſuaded that every rational and unprejudic'd Perſon, who duly conſiders and connects the ſeveral Principles which we have before advanced, will find no Difficulty in this Syſtem of a nervous Fluid.

§. 285. There is therefore no Face of Truth in that Opinion, which aſſerts the Nerves to perform all their Actions by Vibrations, like thoſe which ariſe from ſtriking a *tenſe* [1] Chord or Threat: Since this is repugnant to the Nature of the ſoft, pulpy and flaccid Nerves (§. 284, (4).) which have ſo many Inflections and Incurvations; and alſo inconſiſtent with that very *accurate* [2] Diſtinction with which Objects

Objects are repreſented to the Senſes, and with which the *muſcular* [3] Motions are performed.

[1] Thus, ſays they, a Motion may be communicated from the Brain to any particular Part inſtantaneouſly, in the ſame manner as a Vibration is propagated from one Part of the tenſe Chord to the other without any ſenſible Interval of Time, or as the Motion of the Hand is govern'd variouſly in the ſmalleſt Inſtant to direct the Sword or Cudgel, which they think is hardly intelligible upon any other Principle than that of Vibration; but theſe Gentlemen do not conſider the Impoſſibility of ſuch Oſcillations in the Nerves, which without their Integuments are nothing more than a ſoft Medulla, ſo yielding, that an Ounce Weight will expreſs all the pulpy Subſtance which the optic Nerve received from the Brain; but for a Body to be ſoft and flaccid like a Pulp, and to perform Vibrations like a tenſe Chord at the ſame time, is quite oppoſite to the Nature of Things, and are Conditions that were never yet obſerved in any one Body. But to mollify this Objection, ſome of them will reply, that the Nerves receive their Elaſticity and State of Tenſion from the Meninges with which they are inveſted, and which are apparently elaſtic, as they are continued with the Nerves to the ſeveral Parts of the Body, and occaſion them to contract or ſhrink up, after any Wound or Diviſion; but they ought again to conſider, that theſe Coats make no Part of the Nerves, ſo far as they are Organs for Senſe and Motion, but only ſerve to convey and ſecure them in their Courſe to the ſeveral reſpective Parts, where they are at length depoſited as uſeleſs to the medullary Subſtance of the Nerve itſelf, which alone is the Inſtrument productive of Senſe and Motion. Add to this, that if we ſuppoſe the Nerves

ſtretch'd like tenſe Chords, they wou'd be incapable of performing their Offices; for the moſt elaſtic Chords will neither tremble nor perform muſical Oſcillations, if they are either inflected or in ſo lax a State as the Nerves.

2 The optic Nerve expands its medullary Subſtance for Senſation in the Form of a Cup, which is continued from the Center of the optic Nerve to the ciliary Proceſſes; but if we ſuppoſe this to be a ſolid and tremulous Cup or Glaſs, I ſay that if one Point be ſtruck all the reſt will be likewiſe put in Motion; for the Tremor of a ſolid and continuous Body propagates itſelf throughout the whole, ſo that every Point of the Eye would thus be ſenſible of but one Object, whereas we ſee an infinite Number very diſtinctly at one and the ſame Inſtant, each Object acting on a different Part of the Retina, and conveying its Impreſſion diſtinctly to the Brain, which could not be effected by a tremulous Solid.

3 I am not ignorant that *Swammerdam* has oppos'd Experiments to this Opinion, and has demonſtrated that by compreſſing of the Nerve belonging to any Muſcle of an Inſect, that Muſcle will be convuls'd; and *Steno* having divided the crural Nerve in a Dog, found that by vellicating and pulling the ſame the Foot was directly convuls'd. Add to this, that Vipers and Snakes of all kinds continue their reptile Motion after the Heart has been pull'd out; and a Frog that has had its Heart and Lungs cut out will ſwim upon being thrown into cold Water, alſo an Eel being cut into ſeveral Pieces continues to move about for a long time after; but all theſe are in Reality no Objections to the Exiſtence of a nervous Fluid; for the two firſt Experiments make nothing againſt us, and the reſt only ſhew that the Fabric of the

Nerves

Nerves in cold amphibious Animals is different from that of the Nerves in Quadrupeds and hot Animals; ſo that no Argument of Force can be thence drawn to make any Concluſion with regard to the human Body.

§. 286. In the ſame manner therefore as the arterial Blood and Lymph are perpetually diſtributed or moved into all the vaſcular Parts of the Body, ſo we alſo underſtand that the Juice ſeparated by the Cortex of the Brain and Cerebellum is continually *propell'd* [1] from thence through the Nerves by the Force of the Heart and Arteries into every individual Point or ſolid Particle throughout the whole Body.

[1] And at length returns again from all Parts of the Body to the Spring from whence it came, to wit, the Brain; ſo that that Part of the oily ſubtile Liquor which is ſeparated from the Blood in the cortical Subſtance of the Brain, and paſs'd from thence through the Tubuli of the nervous Syſtem into every even the minuteſt Part of the whole Body to the very ſmalleſt Stamina, are at laſt abſorbed and returned by very minute nervous Veins opening into the viſible lymphatic Veins; from whence paſſing into the lymphatic Cava, *i. e.* the thoracic Duct, it goes from thence into the ſanguiferous Veins, and ſo to the Heart, which again ſends it to the cortical Subſtance of the Brain, to be there ſeparated afreſh and repeat the ſame Courſe many times ſucceſſively; ſo that there ſeems to be a Circulation of the nervous Juice not unlike that of the Blood and other groſſer Humours of the Body.

§. 287. Laſtly, the exceeding Subtilty of the vaſcular Tomentum of *Ruyſch* in the Cortex, (which is yet only the groſſer arterial Fabrick ſending off lateral Branches, decreaſing gradually till they become inconceivably fine Emiſſaries) teaches us how very minute or ſlender thoſe hollow Threads, or ſoft Tubuli of the Nerves muſt neceſſarily be; but if the vaſt *Bulk* [1] of the Encephalon be again compared with this Minuteneſs of the nervous Tubuli or Fibrills, it demonſtrates them to be more numerous than can be conceived within the Bounds of Imagination; and that the vaſt Quantity of Juice forcibly propell'd hither muſt inevitably keep thoſe Tubuli conſtantly open and full for Action.

[1] There is not any one Viſcous in the human Body equal in Size to that of the Brain and its Appendages, to wit, the Cerebellum and Medulla Spinalis conjunctly, which is the larger ſtill as a viſcous, ſince there are no Incumbrances from large Blood-veſſels, Fat, or other Embarraſſments being only a Compoſition of the minuteſt Vaſcules from which the Medulla immediately ariſes; which, being ſo much ſmaller than the ſanguiferous Veſſels, admits of a much larger Number to be wound up in the ſame or a leſs Space. 'Tis true the Injection of *Ruyſch* penetrates into the ſecond or third Series of the arterial Veſſels in this Part, but then the greateſt Part of the Cortex remains ſtill unentred by the Injection. The Lungs conſiſt almoſt entirely of Air-veſſels, and if you waſh out the Blood by injecting Water, then force out the Water

ter by preſſing Air into them, and at laſt dry them, the whole Subſtance of the Lungs appears empty Membranes, replete with Air only; even the Liver, notwithſtanding its great Bulk, would be incapable of filling the cavity of the Spine and Cranium if you conſider the Figure of the laſt, and deduct the large Veſſels which add little or nothing to the Secretion; but if the Liver thus appears leſs than the Brain and its Appendages, you will readily give up all the other Viſcera which are much ſmaller. To conclude then, if you conſider the vaſt Bulk of the Brain, and compare it with the incredible Tenuity of its Veſſels, it will readily appear that the Number of ſecretory Tubuli and Vaſcules therein muſt be infinite, and that theſe latters are continually and equably pervaded by a moſt ſubtile Juice.

§ 288. But we are in the mean time perſuaded that this Juice does not move with any great *Force* [1] through its proper Tubuli or Veſſels, if we conſider the infinite Number, Minuteneſs, Incurvations, and Contexture of the ſmall Arteries through which it is ſtrained; on the contrary, the vaſt Number, ſubtil Diviſions, various inflections, and different Compactneſs of the Nerves in different Parts, prove the Flux thereof to be conſtant, gentle, and *equable* [2].

[1] The Juice of the Nerves flows through them continually, but not with a violent or rapid Motion; for the Flux of all the Juices throughout the whole Body reſults from the impelling Force of the Heart and the elaſtic Contractions of the Arteries, which being ſtrongeſt in the largeſt or firſt Series of

of Veſſels, to wit, the ſanguiferous, gradually weakens as the Juices are thereby protruded thro' the ſeveral leſſer Series of ſerous Veſſels, into which the Force of the Heart is ſcarcely extended; but the Serum and Lymph are rather protruded by the arterial Contractions, which being ſtill leſs as they diminiſh, are divided into leſſer Series, the laſt Series of them will be ſo ſmall and unactive as to protrude their contents very weakly and ſlowly, ſo that the Velocity of the Fluid will be continually diminiſhed as it paſſes from the Heart to the Entrance of the nervous Tubuli or Medulla of the Brain, having communicated almoſt all their Motion to the ſeveral other Juices and Impediments which they meet in the way; but the Nerves are the very ſmalleſt Series of Veſſels, and being the remoteſt from the Heart, the Impetus and Velocity of their contained Fluid will be leſs than in any other Veſſels; and it is neceſſary it ſhould be ſo, if we conſider the very tender and pulpy Subſtance of the Cortex and Medulla, from whence the ſoft Subſtance of the Nerves is continued; which is again another Argument for a very ſlow Motion of their contain'd Fluid. It cannot be ſaid with Juſtice that there is a Mechaniſm in the Brain to accelerate or quicken this ſlow Motion of the nervous Fluid; for the large arterial Veſſels there, which protrude the Lymph in other Parts of the Body, have here little or no Motion from the Thinneſs of their Coats, being like thoſe of ſmall Veins; nor can we expect any ſuch Impulſe from the Motion of the Dura Mater, as *Pachioni* and *Baglivi* have imagined; for the Dura Mater cloſely inveſts the Cranium, and is ſo ſtrictly attach'd to the Bones that it cannot recede from them in the leaſt, inſomuch that its Arteries are rather forc'd to make their Impreſſions upon the Bones themſelves

ſelves by the ſtrict Adheſion of this Membrane. But it does not follow, that becauſe the Motion of this Juice is ſlow that therefore its Action muſt be ſo, for we are aſſured to the contrary, by its inſtantaneous Obedience to the Will in Dancing and other Exerciſes; the Mind no ſooner wills the Extenſion of the Arm but it immediately follows; not becauſe a certain Quantity of the nervous Juice is impell'd at that time all the way from the Brain into the extended Muſcles, but becauſe all the nervous Tubuli being full, an Impulſe communicated to the Liquor at one End of the Tube will thruſt out its Globules at the other End in the very ſame Inſtant of Time; as we know by placing a Row of ivory Balls cloſe to each other upon a Table, and then by ſtriking upon the outermoſt Ball at one End, the furthermoſt at the other End will inſtantly recede or run off with the Velocity firſt communicated, without any ſenſible Succeſſion through the intermediate Balls; and if a Tube be full of Liquor, you no ſooner urge more in at one End but it inſtantly runs out at the other.

[z] This is an Objection, which, upon mature Conſideration, may be eaſily obviated by any one, thus; If the Motion of the Heart be alternate with Intervals of Reſt betwixt each Contraction, then the Motion of the nervous Fluid reſulting from that of the Heart will not be equable and continual, but impeded alternately by Stops whenever the Heart dilates; but we know that the Senſes are continually maintain'd, and therefore the Flux of the nervous Juice muſt be equable and uninterrupted through the Nerves, contrary to the Drift of this Syſtem. But this Difficulty is eaſily removed if we conſider that the nervous Juice moves in its contained Veſſels like the Blood in the Arteries, which never ceaſe to protrude their Contents though

though they do it with an unequable Velocity; the Motion of the arterial Blood being accelerated as often as the Heart contracts, and in the same manner, I suppose, that the Sensations are perpetually maintained, but more exquisite when the Blood is impell'd into the cortical Fabric of the Brain. Agreeable to this *Malpighi* observes that the Light which he perceived as he lay in Bed was not equally vivid all the time, but made with Flashes or sudden Starts of Brightness whenever the Heart contracted itself; 'tis certain the Light itself was the same all the time, only it made a more vivid Impression on the Nerves when they were fullest; whence it is probable that the Impulse or Motion of the Juice in the Nerve is continued from that of the Blood, but is sometimes accelerated and retarded like the last, only the Difference is not sensible, because the first Impulse or Augment of Motion is very little impaired before it is succeeded by a second and a third, *&c.*

§. 289. From what has been said you will therefore hardly *wonder* [1] that the Motion and Existence of this Juice cannot be seen, nor that it cannot be exhibited to the Eye either by *Ligatures* [2], *Wounds* [3], Punctures, Suction, the *Air-pump* [4], or *Injections* [5]; for whoever expects or attempts at these Methods of Discovery, must be ignorant both of the Nature of the Juice and its containing Tubuli: But they who deny the Existence or Perviousness of small Vessels because their Cavities are not demonstrable to the Eye, must be such as are highly ignorant of the original Mechanism of our *Bodies* [6] at first, of their After-growth or In-

Increaſe, and of the ſeveral animal Operations and *Excretions* [7]; they muſt alſo know nothing of the Fabric of *Inſects* [8], nor have taken any Notice of what may be manifeſtly obſerved in Plants.

[1] There have been ſeveral eminent Gentlemen in the Faculty who have thought it apparent there was no animal Spirits or nervous Juice, becauſe none could be exhibited to the Eye. I am indeed myſelf of Opinion that the Art of Phyſic ought to be founded on none but ſenſible Experiments; but then I think we ought not to deny our Aſſent to ſuch evident and reaſonable Concluſions as apparently follow from ſenſible Phænomena. Before *Lewenhoec* invented microſcopical Lenſes of the ſixth Order, there was no one that could demonſtrate to our Senſes or Eyes that the ſanguiferous Arteries and Veins were continuous with each other; but you muſt allow it would have been very raſh and haſty in any Perſon to deny their Cummunication, or the Blood's Paſſage from one to the other, becauſe none ſuch could be then ſhewn to the Eye. The Pulſe is evidently perceptible in the Artery upon its Dilatation from the Blood by the Heart; but no one will deny the Pulſation, which can only be felt, becauſe he does not ſee it, for all we can ſee is the Dilatation of the Artery in the Inſtant only when the Blood is impell'd from the Heart. In the ſame manner we cannot ſee the nervous Juice, but we ſee the Brain and Nerves all grow and increaſe in Proportion with the Heart and reſt of the Body, and therefore conclude that the Brain and Nerves are replete with a Juice which they continually receive from the Force of the Heart. We ought not to invoke the Teſtimony of our Senſes to prove the

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Exiſtence of theſe Spirits; for as *Ariſtotle* wiſely obſerves, we are not able to ſee that which ſees, nor hear that which hears; even to do this would require us to have our ſenſitive Organs ſo exquiſite or ſubtile that they would be incapable of perceiving the external and groſs Fabric of Bodies; and then it was altogether neceſſary for the Liquor itſelf which receives the Impreſſions of Objects to be ſo fine as not to make any Impreſſion on the Organs, otherwiſe the Mind would perceive the included Liquor inſtead of the external Object, and therefore it was not poſſible for any viſible Liquor to be capable of performing the Office of a nervous Spirit.

[2] It is urged by ſome, as a ſtrong Argument, that if you make a Ligature on the Nerves, they do not ſwell betwixt the Brain and the Parts to which they belong, and that therefore they do not carry any Liquor from the Brain into thoſe Parts; but this in fact demonſtrates no more than that the nervous Tubuli are exceeding ſmall: For no one could ever demonſtrate the ſwelling of a lymphatic Artery by Ligature, when it is notwithſtanding a real Artery, and an infinite Number of times larger than any of the nervous Tubuli.

[3] There have been formerly ſome eminent Profeſſors in this Univerſity, who endeavour'd to prove publickly by Experiments, that the Nerves were ſolid Bodies without any Cavities in them. In order to this they took the auditory Nerve, and with a Magnifier endeavour'd to obſerve, whether or no they could diſtinguiſh any Foramina in a tranſverſe Section thereof, or whether they could perceive any Juice run out from the Diviſion; but every unprejudiced Student denied that they could ſee either, whereupon the Profeſſor triumphs and gains the Victory over the controverted Spirits.

But

But for my own Part, I muſt declare my Surpriſe at the Levity of ſuch Men, who are ready to draw Inferences and Concluſions any way, juſt as they are pleaſed to think. 'Tis well known that nobody could ever diſcern the conſtituent Particles of pure Water, even by a microſcopic Lens of the ſixth Order; and therefore by this Rule the Water muſt conſiſt of no Particles becauſe they are not viſible. If a Veſſel of extravaſated Blood be ſet by in a warm Place, the Maſs will gradually diminiſh till it is at length wholly exhaled into the Air; but as you can never diſcern any of the exhaling Particles by the Microſcope, you muſt thus therefore conclude there are no exhaling Particles, when at the ſame time the whole Maſs evaporates in ſuch. From one of the Seeds of the Gourd, which the *Italians* call *la groſſa*, ariſe very large green Leaves, and ſuch Fruit that one of them weighs above eighty Pounds, and ſome of them have been ſent to the Count *Marſigli* weighing a hundred and twenty Pounds: But all this Maſs or Weight of the Fruit has run through the Peduncle or Foot-ſtalk no thicker than a Gooſe-quill within the Space of ſixty Days, notwithſtanding no Tumour will be form'd betwixt the Root and Peduncle, after making a Ligature on the laſt; but it is nevertheleſs vaſcular, and *Ruyſch* has demonſtrated that there is not one Tube or Vaſcule in the Fruit which was not before in the Peduncle. Even the eighty Pounds of Juice in the Fruit is but a little Part of the whole Quantity which paſſes that way; for one of thoſe Gourds ſoon loſes above twenty Pounds Weight of its Juices by Tranſpiration; nor did it perſpire leſs whilſt growing than after it has been gathered: So that if we only make the Weight of the perſpired Juices equal to that of the Gourd, the Amount will be a hundred and eighty Pounds; of

which three Pounds muſt have paſſed daily thro' the Peduncle, ſince there is no other way for it to paſs, as appears from wounding or dividing the ſaid Peduncle, which will not then produce any Gourd; but this Peduncle could not tranſmit ſo many Pounds of Juices without being full of pervious Tubuli to convey them, and notwithſtanding if you tie and cut the Stalk, or endeavour to draw out the Juice by the Air-pump, all will be found to have no Effect in demonſtrating thoſe Tubuli.

4 A certain Profeſſor ſuſpended Part of a large Nerve in the Receiver of an Air-pump, but upon exhauſting the Air no Juice could be extracted from it, and he therefore thought this was an evident Proof that the Nerves did not convey any Liquor. But ſuppoſe the Juice of the Nerves as groſs as the common Air, do you think that Air could be perceived iſſuing out of the Body in an exhauſted Receiver; but the nervous Juice is probably finer, more pellucid and leſs viſible than the Air: Even the nervous Tubuli ſeem to be ſo ſmall, that upon diſſecting them any way, neither their Cavities nor Juices can be diſcerned by the ſharpeſt Eye.

5 Some will ſay if we can inject other very ſmall and naturally inviſible Veſſels, ſo as to render them conſpicuous, why not the Nerves alſo, if they are pervious; to which very weak Objection we anſwer, that the ſmalleſt Veſſels ever injected are probably ſome Millions of Times leſs than the nervous Tubuli.

6 We grow up from a Point next to nothing, even to that Bulk in which we at preſent appear; and yet in that ſmall and inviſible Point were compriſed all, and even more Veſſels than we have at preſent: Since we obſerve all the ſame Arteries in a Fœ-

a Fœtus as in an Adult, in which laſt there are many Parts which were Veſſels in the Fœtus but are not ſo in the Adult (*per* §. 467.). But all this inviſible and human Animalcule is at firſt like a fluid Mucus; and if you therefore aſſert it has neither Arteries, Veins, or Nerves, you will contradict what we have proved to be true in §. 673; but if you ſay it has Veins, Arteries, and Nerves, are they therefore viſible?

7 Through the hard Cutis covered with the horny Cuticle, exhales daily five Pounds of the perſpirable Matter of *Sanctorius*; but *Lewenhoec*, with his beſt Microſcopes, could never diſcern the exhaling Particles; for what he obſerved tranſude through the Skin was only an oily Matter. Who will demonſtrate thoſe odorus Particles to the Eye, which flying off from a Perſon's Skin and Cloths, and adhering to adjacent Bodies, ſerve as a faithful Clue to conduct the wandering Dog through the Meanders of a populous City to his loſt Maſter? yet is the Exiſtence of thoſe Pores and Particles not the leſs certain becauſe inviſible.

8 *Lewenhoec* inſpecting ſome freſh and pure Rain-water, could at firſt diſtinguiſh nothing therein; but after ſtanding a few Days the Water grew foul and turbid, and in it appeared an infinite Number of little Fiſh of various Kinds. Among theſe Animalcule there was one conſiſting of thirty Joints, perpetually turning and winding itſelf about, and at laſt depoſited a great many Eggs, from whence aroſe more Animalcules like the firſt; but for the Motion of theſe there muſt be Nerves, Muſcles, Arteries, &c. Let not any Body therefore deny the Exiſtence of every thing they cannot ſee, ſince there are whole Animalcules, the moſt complex Machines in all Nature, eſcaping the ſharpeſt Eye.

§. 290. But it is even a ſtill groſſer Error to imagine that the very thick, viſcid, and *lymphatic Juice* [1] which iſſues from the Nerves of an Ox's Tail that has been cut off, is that very fine Spirit or Juice of the Nerves we have been now deſcribing: Nor can any Liquor *injected* [2] by the carotid Arteries of an Animal, ſo as to tinge the Nerves, demonſtrate their Cavities or Tubuli: Nor does that *Tumour* [3] which ariſes after making a Ligature on the Nerves of a young Animal, prove the propoſed Argument.

[1] The Exiſtence of a nervous Juice has been as lamely defended by ſome of its Patrons, as it hath been weakly oppoſed by many of its Adverſaries: It even makes me bluſh to mention the Error of the honeſt and otherwiſe judicious *Malpighi* and *Bellini*, who both tell us, that after cutting off the Tail of an Ox or Cow, there diſtils from thence a nervous Juice, thick, glutinous, and apt to harden; for the Juice here mentioned is no more than the Mucilage from the Articulations of the Vertebræ which compoſe the Tails of brute Animals, ſerving to mollify the Ligaments connecting the Vertebræ to each other.

[2] There have been ſome *Engliſh* Anatomiſts who imagin'd that they had deliver'd or demonſtrated the hollow Tubuli and Cavities of the Nerves, becauſe by injecting the carotid Arteries with Urine colour'd with Ink, they found all the Nerves of the Brain tinged with that very penetrating Liquor, and upon dividing any one of them tranſverſly, they appeared full of black Specks or Points, which they ſuppoſed to be the Cavities of the

the nervous Tubuli, but were in Reality no more than the divided Arteriolæ ſpent upon them from the Carotids (*per* §. 235 and 282.); but thoſe ſmall Arteries ſpent on the Coats of the Nerves, and tinged with the injected Liquor, are ſome Millions of Times larger than the medullary Fibres or Tubuli of the Nerves.

[3] Dr. *Willis* endeavouring to refute the Opponents of a nervous Spirit, urges an Experiment which at the firſt Appearance might ſeem next to a Demonſtration; and that is, if you make a Ligature upon the Nerves of Whelps or other young Animals they ſwell betwixt the Brain and the Ligature; but then in Reality this is no Tumour or Turgeſcence of the Nerve, but of the Integuments or including Membranes, furniſhed both with ſanguiferous, ſerous, and lymphatic Arteries, whoſe contained Juices being obſtructed by the Ligature occaſions the Tumour.

§. 291. This Liquor being very ſubtile, perfectly ſimple, fluid and volatile, is therefore termed the *Spirits* [1] of the Nerves, which are, from their Offices, diſtinguiſh'd into *natural* [2], vital, and animal, as we ſhall ſee hereafter.

[1] We chuſe to call them by the Name of (πνευμα or) Spirit, after *Hippocrates*, who by that Denomination underſtood a Fluid capable of exerting conſiderable Forces, without being viſible, like the Wind: And when he divides the human Body into Parts containing and contained, he includes the Spirits among the latter, which were ſecured and governed by the Mind as by a Door-keeper.

[2] The Moderns have rejected the Distinction made by the ancient Physicians of the Spirits into natural, vital, and animal; but I think they have done this without due Consideration: For 'tis probable that the Spirits of the Brain are different from those of the Cerebellum, since their Fabric is different from each other; and we are even furnished with Arguments to prove that the animal Faculties result from the Action of the Cerebrum, and the vital from that of the Cerebellum. Therefore the Spirits of the Brain may be not improperly termed animal, as those of the Cerebellum may be called vital: And for the natural Spirits, those may be so call'd which flow through the minutest Tubuli of the very last Series of Vessels, arising not from the Brain, but intermediately from the sanguiferous Arteries themselves throughout the whole Body; which last Juice or Spirit is neither subservient to Sensation or Motion, but to nourish and repair the smallest Vessels and Fibres in the Body.

§. 292. But since *new* [1] Spirits are supply'd every Moment from the Blood, the last made will drive forwards the preceding, which having performed their ultimate Uses, seem to be finally impell'd into the smallest lymphatic Veins of the Glands and other Parts, from whence passing into the lymphatic Veins of a little larger Size, and from them into the common and visible Lymphatics which have Valves, they are at last returned into the Blood of the sanguiferous Veins, and by them to the Heart, so that this Juice or Spirit has a perpetual

petual Circulation through the Veſſels like the reſt of the Humours.

1 The nervous Juice is preſſed or moved ſlowly and conſtantly through the nervous Tubuli by that Impulſe of the Heart which is communicated from the Blood through the ſeveral decreaſing Series of Veſſels in the Cortex, by which it at laſt enters and paſſes through the very ultimate or leaſt Series of Vaſcules contained in the medullary Tubuli of the Brain. This Liquor muſt therefore have ſome Exit from the nervous Tubuli, or elſe it would be perpetually augmenting: But we aſſign it a threefold Exit, as (1.) when a Nerve having ramified itſelf in the leaſt Branches, ſpends itſelf upon the Stamina, or leaſt and moſt ſimple Fibrils of the Body, and then being reflected back from thoſe Stamina, and gradually enlarging, compoſes a ſort of ſpirituous Veins, the leaſt of any in the Body; which leaſt Veins conveying the nervous Juice into the next larger Series of pellucid Veins, paſſes thence into a third Series, ſo into the lymphatic Veins, which open into the ſanguiferous Veins, and return their Contents to the Heart with the red Blood, which ſeems to be a Courſe much more probable than for the nervous Juice to return back again to the Brain. (2.) All the internal Membranes which inveſt the ſeveral Cavities in the human Body [termed Κοιλιας, Caverns or Caſes, by *Hippocrates*, which he ſays are fill'd either with Spirits in healthy Bodies, or with Ichor in diſeaſed Habits] are perforated with very minute Ducts of various Kinds, ſome of which ſeem to be continued from the nervous Filaments to exhale their redundant Juice in Form of Vapours, to lubricate the Membranes and prevent their Concretion; in the ſame manner as the arterial Lymph tranſudes thro'

the Membranes of the Heart into the Pericardium. But then these exhaled Spirits or Vapours are neither condensed nor retained long in those Cavities, but are quickly again absorbed and returned into the Blood; for in the Ventricles of the Brain there is less of this Liquor to be found in Proportion as the Animal is more lately deceased, and as it was more healthy before Death; and if ever it stagnates or is accumulated in the Ventricles in any Quantity it never fails to produce either an Hydrocephalus, Apoplexy, or Lethargy. It is therefore evident that those Spirits or Vapours are absorbed by the smallest Veins, and by them returned through several Series into the Lymphatics, and so to the Blood; so that we have here two Ways by which the nervous Juices return again to the Heart, for to make repeated Circulations without being wasted or destroyed. (3.) Lastly, some of the ultimate Ramuli or Filaments of the Nerves seem to open through the Skin and exhale some of their contained Juice, every way forming a spirituous Transpiration, as we know there is an arterious one: The threefold Termination of the Nerves before described is confirmed by Termination of the Arteries in the like threefold manner (§. 132. N° 15, 16, and 17.).

§. 293. But if you ask which seems to be the most probable Opinion, whether this Juice finally stagnates in *blind* [1] or impervious Ducts? Or whether it does not rather flow back again to the *Source* [2] from whence it first came? Or lastly, whether one should not rather imagine it all *exhales* [3] out of the Body? I answer, that in Reality hardly either of these seems likely to be true.

[1] There

[1] There have been ſome Profeſſors who have built their Syſtem of Phyſiology upon a Suppoſition that the nervous Tubuli are impervious and turgid with Spirits, performing their Actions by mere Undulations; but that is repugnant to the conſtant Influx of the Spirits, which would inevitably burſt their ſoft including Tubuli, or elſe diſtend them to an immenſe Bulk, if they were not pervious, ſo as to give a free Paſſage to them continually; and there does not ſeem to be the leaſt Foundation for ſuppoſing that they return again to the Brain by the ſame Tubes which diſtribute them from thence.

[2] An *Italian* Phyſician, *Miſtichelli*, has endeavoured to prove a Reflux of the nervous Juice, by an Obſervation he made on the auditory Nerve, which he imagined might be plainly ſeen to paſs through the Cochlea and Canalis Semicircularis, and then to return again to the Brain from whence it came; but it does not ſeem probable that the Auditory Nerve becoming a ſoft Mucus in thoſe Cavities ſhould be compacted again into a Nerve, nor is it confirmed to be ſo, either by anatomical or microſcopical Experiments, and therefore we think that the Notion ought not to have any Credit paid to it.

[3] Not that all of it exhales this Way, for neither are all the Nerves diſtributed to the Skin, nor could we ſupport ſo great a Diſcharge, ſince it is required to be made from the Blood and Chyle.

§. 294. The Blood having been *drained* [1] of its Spirits, ſecerned from it in the Brain and Cerebellum, is then impell'd into the Veins of thoſe Parts, by which Veins it runs from every Quarter of the Encephalon in oppoſite Courſes,

Courſes, both forwards and backwards, into the *large* [2] venous Receptacles termed Sinus's, thence paſſing, at a Diſtance from the Fellow Arteries, through proper Holes of the Cranium into the venous *Sacculi* [3] or Protuberances, and from thence to the *internal* [4] Jugulars, ſo to the Subclavians, and by the Cava to the Heart.

[1] That Part of the Blood which does not enter the cortical Subſtance of the Brain, paſſes into the ſmall ſanguiferous Veins of the Pia Mater; while the more ſubtile Parts of the Blood which enter'd the pellucid Arteriolæ of the Cortex deſcends to afford the proper Matter for Spirits: But as there are no ſanguiferous Arteriolæ in the Cortex, ſo there are not any ſanguiferous Veins there; nor does the Blood paſs immediately from the ſanguiferous Arteries of the Pia Mater into the Sinus's without the Intervention of Veins.

[2] 'Tis a Mechaniſm peculiar to the Brain to have large venous Receptacles, of a different Figure and Make from any of the Arteries and Veins: And the Deſign of them ſeems to be to prevent any Inequality in the Motion or Courſe of the Blood returning from the Encephalon, which would have been unavoidable if the Arteries had accompanied each other in the Cranium as they do in other Parts; for as the cerebral Arteries are ſoft, and have their Tunics much like Veins, they would eaſily become ſo turgid, from various Cauſes, as to compreſs the Veins if they lay near each other, whence the Brain would have been much more liable to Apoplexies than under the preſent Circumſtances. The Creator has therefore wiſely contrived large ven[illegible] Receptacles of a very robuſt Fabric,

Fabric, and placed them at a Diſtance from the Arteries, ſo that they cannot be diſtended as to compreſs the Brain, for their Integuments or Ligamentary Fibres are ſo tough and very little elaſtic that they will ſooner break than give way; but theſe Sinus's are inſerted oblique into the Veins, and are alſo furniſhed with Valves, leſt the Blood ſhould return from the Sinus's into the Veins of the Pia Mater; and it is on the Account of theſe Valves that the Veins of the Pia Mater are ſo difficultly inflated by the Sinus's.

3 Which are four times as large as the lateral Sinus's inſerted into them; by which the unequal Motion of the Blood, whenever that happens in the Brain, is neceſſarily abated, ſince theſe Sacculi or dilated venous Sinus's are lodged in immutable bony Caſes. To theſe jugular Veins is conveyed all the refluent Blood of the Encephalon, not excepting that of the large Veins, which paſs out thro' a particular Foramen of the Cranium, and at laſt terminate in the Jugulars.

4 Which are placed ſecure from any Compreſſion by the Muſcles, and do not protrude the Blood by the common Force of the Heart; but when the Heart is relaxed and empty, the Blood of the Jugulars finds a ready Entrance, and is every Way ſecured from Compreſſion. But there is a Valve placed at the Entrance of the jugular Vein into that of the ſubclavian, leſt the Blood ſhould be forced out of the latter into the former, when it is obſtructed in paſſing thro' the Lungs, as when a Perſon laughs.

§. 295. In the mean time the *Lymph* [1] of the Encephalon, like that of all other Parts, being ſecerned from the arterial Blood thro'out the

the *whole* [2] Cerebrum and Cerebellum, is all returned, together with the Lymph that tranſuded into the Ventricles; and entering the lymphatic Veins proper to the Encephalon, *Infundibulum* [3], and pituitary Gland, comes at length into the Jugulars, and at laſt to the Heart. So that there is alſo a perpetual Circulation of Lymph throughout the Encephalon.

[1] Or the moiſt Vapours with which all the Membranes are lubricated, and with which all the Contents of the Cranium are bedew'd; which Vapours are even eaſily perceptible to the naked Eye when the Cranium of a living Perſon is trepanned; for in that Operation Vapours exhale from the whole Surface of the Brain.

[2] That is (1.) thoſe Vapours betwixt the concave Surface of the Dura Mater, and the convex Superficies of the Pia Mater, which prevent the Concretion, or any Adheſion of thoſe Membranes, mollify and relax their Veſſels, and expedite the Circulation through them. (2.) The Vapours betwixt the Hemiſpheres of the Brain above the Corpus Calloſum. (3.) The ſubtile Dew which tranſudes throughout the whole internal Superficies of the anterior Ventricles. (4.) Where the poſterior Lobes of the Brain are ſupported over the Cerebellum, and diſtinguiſhed by the Cruciform Production of the Dura Mater. (5.) In the fourth Ventricle where the Medulla of the Brain and Cerebellum meet with each other. (6.) In the Baſis of the Cranium where the inveſting Dura Mater ſuſtains the Baſis of the incumbent Brain.

[3] The Infundibulum is one of the Emiſſaries of the Ventricles, which was firſt taken Notice of by *Lower.*

Lower. From the ſecond Ventricle the Vapours are condenſed and convey'd to the third, and from thence they deſcend by the medullary Infundibulum to the pituitary Gland, where being abſorbed by the Veins, they are by them returned into the Blood. But theſe Vapours do not all ariſe from one Part of the Brain only; for Dr. *Ridley*, who has in the Anatomy of this Part cautiouſly endeavoured neither to deceive himſelf nor others, demonſtrates that a great Part of the Plexus Choroideus is compoſed of pellucid and valvular Veins, which are in Reality mere lymphatic Veſſels, diſcharging their vapoury Dew and Juice into the fourth Sinus, from whence paſſing to the lateral Sinus's they at length return by the jugular Veins to the Heart. And theſe are the two principal Ways by which the moiſt Vapours or lymphatic Juices of the Encephalon are naturally abſorbed and returned into the Blood. But if this Moiſture is any way retained and accumulated, it is follow'd either with a Lethargy or Apoplexy: And ſometimes it has been found retained to the Quantity of two Ounces.

§. 296. From what has been hitherto ſaid on this Viſcus we are enabled to anſwer to the following Queſtions: As why the Cerebrum and Cerebellum, with their Appendices, are defended with a *Caſe of Bones* [1], and what Advantages reſult from that Defence? Why the *whole* [2] ſpinal Medulla is lodged in the Chain or Caſe of Bones termed Vertebræ, and without the Incumbrance either of *Muſcles* [3], Glands or *Fat* [4]? Why the carotid and vertebral Arteries never convey the *red* [5] Parts of their

their Blood into the cortical Subſtance? But ſpend their ſanguiferous Branches *only* [6] upon the Surface of the Pia Mater, and betwixt the winding Ridges and Furrows of the Encephalon? And why thoſe Arteries do not run together with their correſponding Veins, but take a *different* [7] Courſe and paſs through diſtinct Holes of the Cranium? Why the venal Blood of the Encephalon is returned into particular Sinus's, and why it does not again paſs ſtrait forwards in thoſe Sinus's? Why the ſanguiferous Veins, being very much diſtended, are never obſerved in the Cortex, but are ſpread only on the *Superficies* [8] thereof and inſinuated in the Furrows betwixt its Gyri? Why thoſe Veins diſcharge themſelves immediately in oppoſite Directions into the *Sinus's* [9]? Why a thin and *black colour'd* [10] Liquor being forcibly injected by the Carotid, and even broken Threads of the ceraceous Injection itſelf, are ſometimes found in the Cavity of the ſuperior Sinus's? And whether they do not enter theſe Sinus's becauſe the Arteries of the Pia Mater communicate by patulent Anaſtomoſes with the Veins opening into thoſe Sinus's, and into which the Injections paſs? Why the Cavities of the Sinus's are ſtrengthened by muſcular Threads or tranſverſe Ligaments? Why the Encephalon is *ſpherical* [11], with the Uſe and Neceſſity of the *Ventricles* [12]? The Compoſition and Uſe of the Plexus *Chorcides* [13]. The Uſes of the *Falciform* [14], and other Proceſſes of the Dura Mater.

ter. Why the *Cerebellum* [15] is without Ventricles, and placed by itſelf, more ſecure than the *Brain* [16]? Why the ſoft Nerves are not *compreſſed* [17], but paſs out freely from the ſuperior Maſs of the Brain and Cerebellum? And laſtly, whether the *Origin* [18] and Termination of all the Nerves is in the *pineal Gland* [19]?

[1] We know of no other Part of the Body that enjoys this Privilege beſides the Brain and its Appendages, with the Marrow of the Bones. But the Reſiſtance and Stability of this Caſe of Bones, the Cranium, occaſions the Brain never to ſhrink or waſte even in Conſumptions; and prevents it from enlarging at any time. And the ſpinal Medulla ſtanding in need of the ſame Defence, is alſo depoſited in the Cavity of the Vertebræ, a Chain of Bones which not only defend and ſecure their tender and important Contents, but are alſo movable at the ſame time by a ſurpriſing Mechaniſm of Articulations and Proceſſes; the ſpinal Proceſſes at the ſame time preventing the Vertebræ from receding ſo far from each other, as might expoſe the ſpinal Medulla behind.

[2] The Cortex and Medulla of the Brain are of ſo tender and ſoft a Texture, that the leaſt Force wounds or diſſolves them; and therefore it was abſolutely neceſſary, as well from their Fabric as important Uſes, that they ſhould be thus guarded from all external Injuries.

[4] As the Action of the Muſcles is neither conſtant nor equable, but alternate and violent, if the Brain had been expoſed to their Preſſure, all its Juice would have been ſuddenly expreſſed and diſcharged without leaving any Supplies; ſo that the Influx

Influx of nervous Juice would have been alternate, as would conſequently have been the Effects thereof, alternate Fits of Senſation, Motion, *&c.* as *per* §. 235. according to *Pacchioni.*

4 As we never obſerve any Fat about the Brain in a healthy State, ſo there are no Uſes for it in this Viſcus; for there is no violent Motion or Attrition of Parts to be thereby abated, nor any acrid Humour to be obtunded: Nor is there any room for Fat, ſince the whole Capacity of the Cranium is fill'd with the ample Cortex and medullary Subſtance, which to have loaded with Fat would have been followed with the moſt dangerous Conſequences; ſince the Quantity of Fat inveſting any Part varies at different times, being ſometimes more and ſometimes leſs, whence the Brain wou'd have been at one time relaxed, and at another time compreſſed, ſo as to prove deſtructive to the Animal; eſpecially ſome that I have often ſeen upon the Shambles, where the vaſt Muſcles of an Ox was ſcarce perceptible, being buried in Fat. 'Tis indeed true, that *Ruyſch* has ſometimes found a little Fat betwixt the Pia Mater and tunica Arachnoides; but this only in Brutes, which were hereby become quite ſtupid, and wou'd ſoon after have died apoplectic, and therefore the Appearance of Fat about the Brain is always preternatural or morbid.

5 To ſave room; for the only Deſign of Nature being the Separation of Spirits, ſhe has therefore only ſupplied this Part with the ſmaller Series of pellucid Veſſels, fit to tranſmit the more ſubtle and ſpirituous Parts; ſo that neither any of the red ſanguiferous, nor any of the yellow ſerous Arteries are diſtributed within the Subſtance of the Cortex.

And

[6] And that partly in order to communicate Heat, which is generated by the red Blood only; and partly to augment the Surface of the Cortex.

[7] By Exercise, or an increased Action of the Muscles, Heart and Arteries, the Blood becomes so attenuated, rarified, and accumulated in the Arteries, as to distend them beyond their usual and proper Diameters, so as to compress the adjacent and less resisting Veins; and for this Reason provident Nature has placed the Veins close by the Sides of the Arteries in many Parts, where the sluggish venal Blood wants to be urged forwards in its Vessels: But if this had been the Case with the carotid Arteries, upon any Compressure or Distention of them by bending the Neck and Head in Sleep, by Exercise, Drinking *&c.* they would by their greater Distention compress the jugular Veins, if they passed out of the Cranium thro' the same Holes with the Arteries, whence would arise the most dangerous Symptoms, if not an Apoplexy and Death. Thus Wrestlers have some of them the Craft to twist the Shirt-collar of their Adversary so as to compress the jugular Veins, whereby his Antagonist loses all his Strength, and becomes unable to stand on his Legs. *Streno* furnishes us with an Example of an Apoplexy induced by a Ligature on the jugular Veins of a Brute; and it is the same with those who are hanged or strangled by the Executioner, for they all die apoplectic.

[8] Because the Cruor or red Blood does not penetrate into the Substance of the Cortex.

[9] Most of the other Veins in the human Body run by the Sides of Muscles, whose Contractions propell forwards their thick and slowly-moving Blood; but it is evident from the Mechanism and Use of the Brain, that no Muscles cou'd be admitted about its tender Fabric, and therefore another

Contrivance is uſed to render the Circulation free thro' this Part, *viz.* large Sinus's or membranous Receptacles into which the ſmall Veins immediately diſcharge themſelves. But theſe Sinus's are again placed ſo as to be free from all Compreſſure, the longitudinal Sinus betwixt the two Hemiſpheres of the Brain, and the reſt in other Parts of the Baſis of the Cranium, where the Inequalities of the Bones guard and defend them alſo from any injurious Compreſſure. The ſame Obſervation is alſo applicable to the Veins which form Rings about the Medulla Spinalis within the Cavity of the Vertebræ, being a ſort of Sinus's free from any muſcular Compreſſure, into which the ſmall Veins of the ſpinal Medulla immediately diſcharge themſelves.

[10] Dr. *Ridley* has obſerved, that ſome of the ſmall Veins proceed backwards from the Fore-part of the Brain, to open into the Sinus's, and others come forwards to their Inſertion; by which oppoſite Inſertion of the Veins their Blood ſuffers a Colliſion and Attrition of its Parts, as it is poured into the large Sinus or Receptacle, and thus its Concretion is in ſome meaſure prevented, to which the venal Blood of the Encephalon muſt otherwiſe have had a greater Propenſity than that of other Parts. 'Tis alſo peculiar to the Veins of the Brain to meet in returning Angles, whereas the Veins of Muſcles and moſt other Parts concur in acute Angles.

[11] See §. 234. Even in this Experiment we find *Ruyſch* and *Raw* agreeing, who are hardly ever of the ſame Opinion in any one thing beſides: *Ruyſch* always found little diſtinct Cylinders or Threads of the Injection which had tranſuded into the Sinus's; which Threads of the Wax or Injection reſembled thoſe he obſerved in the Veins of the Pia Mater after injecting that Membrane.

Becauſe

[12] Becauſe under a Surface of that Figure may be comprized a Body of the largeſt Quantity, and at the ſame time that the vaſcular Strata of the Cortex might be the more orderly diſpoſed one within the other; and that the Center or Medulla might be leſs preſſed than it would have been in any other Figure; for the Cortex being ſpherical, one Part of it ſuſtains the other.

[13] Beſides what has been ſaid at §. 272, we ſhall demonſtrate hereafter (§. 534.) that theſe Ventricles conduce to the alternate Viciſſitudes of Sleep and Vigilance, by a Compreſſure of the Medulla of the Brain.

[14] The whole Plexus Choroides is a Membrane upon which a few ſanguiferous and pellucid Arteries, and many more Veins, are orderly diſpoſed and diſtributed within the Ventricles of the Brain; from whence the pellucid Veins abſorb the tranſuſed Vapours or Moiſture of this Part, by their ſmalleſt Orifices, and then return them into the Sinus's. But theſe moiſt Vapours exiſt here of Neceſſity, becauſe all dry Membranes fret and cohere together without them in a little time; whence we obſerve, that the Pleura having had its exhaling Veſſels deſtroyed by an Inflammation of that Membrane, it afterwards readily adheres to the Lungs, and if the Adheſion be large, leaves an Aſthma behind, which is inflexible to all the Medicines in the World: But were the Membranes of the Brain to adhere in the ſame manner, the Conſequences would be much worſe than an Aſthma; to prevent which therefore the Choroide Plexus exhales a moiſt Dew by its evaneſcent lymphatic Arteries, which is again abſorbed by the Veins. Add to this, the Plexus we are ſpeaking of ſerves to communicate the Heat of the arterial Blood to the cold Medulla,

and at the ſame time alſo to promote the Courſe of its Juice into the Nerves.

15 When a Ball is flung on the Parchment of a Drum that is braced, it does not ſtand ſtill, but flies back in a contrary Direction; and in the ſame manner when one Hemiſphere of the Brain is by any Shock urged againſt the tenſe falciform Proceſs of the Dura Mater, the Concuſſion is broke off both from itſelf and from the oppoſite Hemiſphere; and this longitudinal Production of the Dura Mater alſo prevents one Hemiſphere from compreſſing the other by its ſuperincumbent Weight, when we lay down the Head on either Side. But the longitudinal Sinus ſerves to forward the Courſe of the venal Blood of the Encephalon, which is not promoted by the Pulſation of the Arteries, as it is in many other Parts (*vid.* §. 234.) The cruciform Proceſs of the Dura Mater betwixt the Brain and Cerebellum does alſo anſwer the ſame Uſes with the preceding

16 In this Part the Vitality of a Perſon more immediately reſides, and therefore it is ſo placed as to lie ſecure from all Injuries but what hurt the Brain at the ſame time; for the poſterior Lobes of the Brain extend themſelves farther backward and downward than the Lobes of the Cerebellum which are placed more forward. But on the lower and Back-part the Cerebellum is defended externally by ſtrong Muſcles, which make up for the greater Thinneſs of the Cranium there. 'Tis alſo upon the ſame Account, *viz.* the Importance of the Cerebellum with regard to Life, that the vertebral Arteries are ſo well ſecured and defended in their Paſſage to it, aſcending through the Foramina of the tranſverſe Proceſſes of the Vertebræ in the Neck, ſo that they are hardly ever wounded or injured.

17 It was neceſſary for the Brain to be able to ſuffer ſuch a Change, that it might perform its Actions at one time and abſtain from thoſe Actions the other half of Life; it is therefore furniſhed with Cavities or Ventricles, which, being empty, the Brain is in a manner relax'd, but when full it is in ſome meaſure preſs'd, and in a State of Tenſion. But the Cerebellum having no ſuch Ventricles is therefore not liable to ſuch Viciſſitudes, but continually labours to carry on the vital Functions.

18 Becauſe the Proceſſes of the Dura Mater which ſuſtain the Cerebrum are ſo ſtretched over the Protuberances in the Baſis of the Cranium as to prevent its incumbent Weight from compreſſing the ſoft Nerves. The optic Nerves paſs out of the Cranium under a ſtrong Production of the Dura Mater, which ſerves for a Caſe to the ſaid Nerves, and the other Nerves are ſecured in like manner. But ſometimes when a Man jumps or falls down from a high Place upon his Feet in an erect Poſture, the Repercuſſion from the Earth forces the Brain towards the upper Part of the Cranium, by the Re-action of which laſt the Brain is again forc'd ſo violently upon the Baſis of the Cranium as to compreſs the Nerves which there ariſe from it, ſo as to render the Perſon ſtupid, or without the Uſe of his Senſes for ſome time.

19 Wherever the Cortex terminates there the Medulla of the Brain begins, and ſo does alſo that of the Nerves; to wit, in the whole Circumference of the anterior Ventricles, and from every Point of the Cortex of the Cerebellum; the Origin of the firſt of theſe was obſerved by *Vieuſſens*, but he improperly named it Centrum Ovale; ſo that the nervous Syſtem does not ariſe from any one Point but from diſtinct Parts of the Encepha-

lon, and their Terminations is alſo diſtinct throughout every Part of the Body.

20 No body will eaſily believe that the forty Pair of Nerves which come out of the Cranium and Medulla Spinalis, ariſe from ſo ſmall a Part as the pineal Gland, which is ſo frequently diſtended, putrefied or render'd ſchirrous in many Diſeaſes of the Brain, without any Injury thence ariſing to the Senſes, and which is laſtly placed at a Diſtance from the Brain and Cerebellum. Every intelligent Perſon who conſiders theſe Circumſtances, will not eaſily believe the Notion of *Carteſius*, who placed the Origin and Termination of the whole nervous Syſtem in that Gland, when at the ſame time the pathetick Nerves only riſe near it; however it muſt be confeſs'd, that the Uſe of this Part is not yet ſufficiently known. *Quere:* Whether its Fabrick is not like that of the Cortex of the Brain, or whether it does not ſerve to abſorb the moiſt Vapours and Juices ſubſiding to the Baſis of the Cranium in the manner of a Tunnel?

§. 297. And indeed the Fabrick of the Encephalon will evidently appear to every one who duly conſiders its whole Mechaniſm before deſcribed, to be formed with the higheſt and moſt adorable Wiſdom, its Veſſels being ſo diſpoſed as to carry on an equable and conſtant Circulation and Secretion of their contained Juices; and it will alſo appear to be continually warmed both by the adjacent venal and arterial Blood, ſince the very minute and pellucid Veſſels of its Compoſition would be otherwiſe deſtitute of Heat; and laſtly, the returning Lymph will appear to meet with a ready

ready Entrance and Commixture with the venal Blood of the Sinus's, let the Head be retained in any Poſture whatever.

[1] The medullary Subſtance of the Encephalon is, of all Parts of the Body, much the remoteſt from the Heart, the Source of animal Heat; it was therefore neceſſary for it to receive Warmth from the adjacent external Arteries, partly from the Dura Mater, with the numerous Arteries of the Pia Mater; partly alſo from the Arteries of the Plexus Choroideus with thoſe little Arteries which deſcend perpendicularly from the Pia Mater betwixt the medullary Fibres: Add to this, that the venal Blood is warmer than the Lymph, and therefore the medullary Part of the Brain may receive ſome Warmth from the Sinus's, and from the Veins in the Plexus Choroideus.

§. 298. But the Blood having performed its Office in the Encephalon, returns afterwards diluted with the Lymph of the Brain, and mixing with freſh Lymph, Chyle, and venal Blood with the returning Bile, and perhaps Spirits in the larger Veins, it is from them received into the Heart, which propells the ſame into the Lungs, where it is again changed (*per* §. 200.), and puts on the ſame Diſpoſition which it had before it was firſt ſent to the Brain.

§. 299. And if no crude or indigeſtible Particles remain in the ſaid returning Blood, it will all again, by this new Apparatus only (§. 298.), become the beſt fitted to ſupply

fresh Spirits again, by the Fabric of the Brain and Cerebellum.

§. 300. 'Tis therefore probable that a certain *Portion*[1] of the whole Mass of Blood (§. 224.), does thus pass to and from the Encephalon, in the Course before described, without any considerable Mixture with other Blood of a different Nature; whence it will be the better disposed to circulate the same Way again, more frequently, swiftly, and equably.

[1] That namely which is the most compact, solid, and moveable, being also repleniſhed with the Spirits returning from the Veins, which Part of the Blood will therefore be the more apt to return again to the Brain, and to circulate through it more frequently and swiftly, since the Passage of the Blood from the Heart to the Encephalon is direct, and without any Obstruction from Fat, Muscles, or other Impediments; but as similar Causes generally yield similar Effects, and as the Blood was better disposed than the rest of the Mass to ascend to the Head at the very first Moment of its entering the carotid Arteries, by that Disposition it will also be carried rather to the Brain than to any other Part.

§. 301. Lastly, If we consider (1.) the great *Bulk*[1] of the Brain, Cerebellum, Medulla Oblongata and Spinalis, with the vast Number of large Nerves which proceed, and are distributed from them every way, and then compare the whole System with the Bulk of the other *nearly*[2] solid Parts of the Body; (2.) That

(2.) That the Encephalon and spinal Medulla are the first apparent Basis of the Carina or incipient *Embryo* [3], from whence the rest of the Viscera and other Parts are afterwards produced, as we are assured by the accurate *Malpighi*; and (3.) that there is scarce any Part of the whole Body but what is invested either with the Faculty of *Sensation* [4] or local Motion: From all these Considerations we may believe that almost the whole Mass of the solid Parts in the Body are complicated and made up with nervous Filaments.

[1] As not being loaded like other Parts either with Air, Blood, or Fat, or Muscles, but is entirely a Compages of minute Vessels, giving rise to the Nerves; with which vascular Compages is fill'd the large Cavity of the Cranium and Vertebræ, and which is in reality continued through every individual Part of the Body, by those innumerable Productions the Nerves.

[2] The true or compact Mass of an Animal is not such as appears to us; for, in the first Place, there is a large Quantity of Fat to be deducted, since the Animal may live very well without it and becomes more active thereby. The Limbs of a Patient who has an Ulcer in the Lungs shrink up almost to nothing, without losing any thing but their Fat and Juices, which soon return again after the Lungs have been restored to their healthy State. In the second Place, we must deduct a vast Quantity of Air from the Bulk of the Animal, since we find that the Lungs, Cavity of the Thorax, Stomach and Intestines, Abdomen, *&c.* are almost entirely fill'd with that Fluid. Thirdly, we must deduct the Blood and its Juices, which only distend

stend the Vessels, Muscles, and Viscera to that Size in which they usually appear. Lastly, let the Nerves be deducted or separated from all the rest, and considered as Appendages of the Encephalon, and then upon comparing the nervous System with what remains, it will be found nearly, if not more than equal; for the Brain is destitute of all those Parts which serve to make up the Bulk of the Body, such as Fat, Muscles, Air, Blood, *&c.* and may be therefore consider'd as a mere Solid, excepting the subtile Juice it contains. In an Atrophy or Consumption, the small Blood-vessels are emptied of their Contents and collapse together, but the Nerves do notwithstanding appear as large and as sound as ever.

3 We have beautiful Experiments and Observations on this Subject communicated by *Malpighi*, assisted by the Microscope, though we have many of the same Observations in *Aristotle*, *Aquapendens*, and *Harvey*, who had not the Advantage of that Instrument; from them it appears that every single Egg which does not receive the Influence of the Cock consists of a Shell, Membranes, Chalaza, Albumen, and Yolk, with the Sacculus of Colliquamentum; and that upon opening another Egg, laid soon after the Hen had been trodden, the Sacculus or Colliquamentum appear'd by the Microscope to contain a Speck in its Middle, hardly bigger than the 1000th Part of a Grain of Sand, nor could any distinct Parts be observ'd therein; but upon opening another Egg that had been laid some Hours, he began to distinguish the Carina or incipient Chick in the Form of a Vermicle, or like a Tail arising from a large Head; and it is observable, that all Animals, whether Quadruped, Fowl, Fish, or Insect, are, at their first Formation, of the same Shape, that is, like a Vermicle, consisting

ing only of Head and Tail; in the first of these, after a short Incubation, he distinguished two Vesicles or Hemispheres of the Brain, with the two protuberant Balls of the Eyes, while the Cerebellum appeared in Form of but one Vesicle, with the Medulla Spinalis extended from thence in the Form of a crooked Tail. After a few Hours Incubation all these appeared yet more distinct, and the Carina was beset with Protuberances, or Inequalities, which were the Rudiments of the incipient Vertebræ; at the same time appeared, by degrees, a kind of vibrating Arch extended from the middle of the Carina, which at length distinguished itself into four Sinus's, and being combin'd together form'd the two Auricles and Ventricles of the Heart; there was as yet no Appearance either of the Thorax and Lungs, or of the Abdomen and its Viscera, much less of the Extremities or Limbs, but all those Parts germinated by Degrees till the whole Chick was compleat. If these Observations be considered with due Attention, the nervous System will appear to be the Part which first exists in the incipient Animal; and from whence, in Conjunction with the arterial System, all the Viscera and other Parts are gradually form'd; hence it is that the Head bears so much greater Proportion to the rest of the Body, as the Animal is nearer to its Origin; and on the contrary, that the Viscera and Limbs are proportionably larger as the Animal is older. It is a Rule with Painters to give the Head of a new born Infant the Proportion of one to three in drawing its whole Body, but in Adults the Proportion is one to eight; whence it seems probable, that all the solid Parts of the Body are form'd by Degrees from the Brain and its Appendages, and that they consist chiefly of nervous Filaments.

All

4. All the Parts of an Animal have either Motion or Sensation; and though the Heart, Lungs, and most of the other Viscera, have not a distinct Sensation, as being design'd to perpetual Motions, yet they are formed to be very sensible of Pain or a sort of Anguish whenever they are inflam'd; but if they had been made very sensible they would have received Pain from their necessary and constant Motion; the Bones indeed are said to have no Sensation, but Anatomists are very well acquainted that the compactest Horns arise from soft nervous Papillæ, and that the Nerves being form'd into a membranous Expansion give rise to all the Bones and Cartilages.

§. 302. It will also appear to be in no wise absurd for us to believe, that the smallest Vessels in the whole Body arising from the ultimate Arteriolæ become very much *like* [1] the least Filaments of the Nerves, both as to Size, their contained Juices, and other Properties.

[1] The Aorta is a Compages of all the Series of Vessels; for there are Branches arising from thence, which, being extended into Circles, are at length turned into Veins, lacteal Ducts, adipose Cells, *&c.* Even the whole Body will appear to consist of Arteries if we consider its Nutrition. I cannot, for my own Part, see any Reason why the smallest Series of Arteries, which are the pellucid Emissaries of the Carotids spent in the Cortex of the Brain, should not, some of them at least, be distributed for other Uses than Sense and Motion; for Experiments convince us that those Actions depend entirely upon the Nerves which arise from the Brain.

Even

Even if we meet with Vessels of the same Tenuity with the Nerves in any Part of the Body, their contained Juices must be of the same Subtilty with the Spirits or nervous Juice, §. 275 and 276. so that thus we shall have a sort of Nerves or Vessels of the minutest Size, not arising from the Brain, and whose contained Juices approach very near to the Nature of animal Spirits, being design'd for Nutrition, and therefore we call them natural Spirits.

§. 303. But that Part of the Blood which was sent to the Head, and not employ'd there for the Formation of Spirits, is carried off by the *lateral Arteries* [1] to the Dura Mater, Cranium, Pericranium, Muscles, and other Parts about the Skull.

[1] Both the external and internal Parts of the Head; neither of them receive any Blood but what comes from the carotid and vertebral Arteries; the first of which having reached the Cranium, sends off each a lateral Branch externally, while the internal Carotid is inflected at its entering through the crooked Foramen observed by *Lower*, from whence it is distributed through the whole Substance of the Brain; but the other Branch or external Carotid, being distributed to the external Parts of the Head, sends off a Branch, which passing through a small round Foramen in the Cranium is spent upon the Dura Mater, the Impressions of whose Arteries are visible within the dried Skull; and it is from hence that the Palpitation and Heat of the Dura Mater arises.

§. 304. But the Dura Mater being alſo the internal *Perioſteum* [1] of the Skull, is a ſort of Stratum or Baſis in which thoſe Arteries (§. 303.) are orderly diſpoſed, and from whence they inſert their ſmall Twigs into the Bones themſelves of the Cranium, upon which they are every way ſpent in very minute Branches; but theſe ſmall Arteries being diſtributed betwixt the thin bony Plates of the Cranium, intermixt with thoſe from the Pericranium, and with them form very fine Plexus's, by which the Nutrition, *Warmth* [2], and Secretion of the *Medulla* [3] in the Diploë, with the Growth of the bony Cranium *in Proportion* [4] to the Increaſe of its contained and other Parts, are all performed; but having performed theſe Offices, the Blood ſpeedily returns by the Veins.

[1] From that Branch of the external Carotid which is diſtributed upon the Dura Mater ariſe an infinite Number of ſmall Arteries, inſerting themſelves from the convex Surface of the Dura Mater, through the internal Plate of the Cranium into its Diploë or Meditullium, upon whoſe Cells they are ſpent in reticular Plexus's. In the Skull of a Man that has been hang'd, theſe ſmall Arteries (which ſerve as ſo many Ligaments to connect the Cranium and Dura Mater) being burſt, occaſion the Appearance of many red Points or Spots in the Dura Mater. Other Branches of the external Carotid are again diſtributed on the Surface of the Pericranium, from whence they penetrate through the external Plate to the Diploë, and mixing with the

the former Arteriolæ compoſe the Meditullium and diſcharge a medullary Oil.

2 The Brain being naturally very cold from its Remoteneſs from the Heart, is in ſome meaſure warmed by the adjacent Arteries of the Dura Mater; which alſo communicate ſome ſmall Motion to its cold Veins, which is one of the principal Offices of the Dura Mater towards the Brain. It is true, that *Baglivi*, and ſeveral other eminent Phyſicians, have imagined that the Action of the Dura Mater and its Arteries is ſo conſiderable as to compreſs the Brain, and propell its contained Juice alternately with every Syſtole of the Heart; but notwithſtanding their Authorities, we know that the Coheſion of the Dura Mater to the Cranium is ſuch as to cauſe its Arteries to make their Impreſſions on the Bones of the Cranium; whereas if the Dura Mater were looſe, we ſhould have the Figure of thoſe Arteries impreſs'd upon the ſofter Subſtance of the Brain. To this it has been objected by a Perſon of Note, that there was a time in which the Cranium was equally ſoft with the Brain; to which we anſwer, that it is evident the Arteries do not make their Impreſſions at that time, ſince their Magnitude correſponds to the Arteries of an Adult, which vaſtly exceed thoſe of the tender Fœtus.

3 There is not indeed much Medulla here ſeparated, but yet there is enough to prevent the Bones of the Cranium from being too brittle; for the Bones themſelves are almoſt a mere Earth, friable, and with little Coheſion, as appears from chemical Experiments, as in a calcin'd Bone, which being dipt in Oil recovers its Hardneſs and Coheſion; this Effect of the Medulla is much greater in the tubular Cavities of the more

movable

movable Bones, as in the Thighs, Legs, and Arms.

4 The Arteries of the Dura Mater, by propelling their Blood and Juices with which they are diſtended by the Force of the Heart, do, in the ſame Proportion, gradually diſtend and enlarge the ſoft Bones of the Cranium, whoſe Sutures continue membranous ſo long as they are capable of Increaſe, that is, to about the Age of twelve or fourteen Years. But the reductory Veins coming through particular Foramina of the Cranium, very rarely open into the Sinus's of the Dura Mater, as *du Verney* obſerves, but are generally inſerted into the Branches of the external jugular Veins. But beſides the Uſe of the Dura Mater, as a Perioſteum, it alſo ſends out Productions through the Foramina of the Cranium and Vertebræ of the Spine, to inveſt and ſecure the Nerves; but theſe Productions reflected, inveſt alſo the Outſide of the Cranium and Vertebræ; from the laſt of which the Continuation is carried on to the Ribs, Clavicles, Humeri, and all the Bones of the Limbs, ſo, in ſhort, as to be continuous with the Perioſtia, and inveſt all the Bones; whence the Dura Mater may be reckon'd the Origin of all the Perioſtia, which, if they could be artfully ſeparated from all the Bones, would exactly reſemble the outward Shape of a Skeleton. All theſe Perioſtia we know are Membranes, ſpread with vaſcular Plexus's, or an infinite Number of ſanguiferous and lymphatic Veſſels, in a reticular Diſpoſition, from whence the vital and nutritious Juices are conveyed into the Subſtance of the Bones, as Dr. *Havers* has ſhewn at large in his elegant Treatiſe on the Bones.

§. 305.

§. 305. 'Tis next obſervable, that the Blood which comes neareſt in Likeneſs to the Conſiſtence or Solidity, Subtilty, Motion and Fluidity of that lately ſent to the Head, is impell'd through the *ſubclavian* [1], axillary, and brachial Arteries, into thoſe of the *Hands* [2]; where paſſing through the leaſt Veſſels like the former, it occaſions that great Agility, Strength, Warmth, and ſenſible Perſpiration obſervable there; for which ſame Reaſons its Circulation muſt alſo be very quick thro' thoſe Parts.

[1] Theſe Arteries are ſo denominated from the Clavicles, under the Defence of which Bones they paſs ſecurely to the Arms in Men who go erect; but in Brutes who have their Necks pendulous, they paſs into the upper or anterior Limbs without this Defence. We however obſerve, that thoſe Animals who uſe the fore Limbs for catching their Prey and other Food, have theſe Bones or Clavicles given to them by Nature, to ſuſtain the Scapula and Articulation of the Humerus, to enable the latter for moving in larger Circles; ſuch as in the Species of Monkeys, Bears, Squirrels, Dormice, *&c.* which have alſo a ſhort Neck like the human Species, and take their Food too like them, either erect or ſitting.

[2] We become almoſt as wiſe by our Hands as by our Eyes; ſince it is the Hand that makes thoſe various Machines by which we are let into the Knowledge of Nature: They make Teleſcopes for us to look into the Heavens, Microſcopes to inſpect and diſcern inſenſible Objects, *&c.* And

therefore to enable theſe Limbs for performing their numerous, nimble, and exquiſite Operations, it was neceſſary they ſhould be ſupplied with the more active, fluid, and ſwiftly-moving Parts of the Blood, as we find they are by the adjacent Heart, next after the Head; whence the Heat and Sweating of the Palms.

§. 306. But the Blood ſent to the Hands, as well as that brought to all other Parts, being ſeparated and diſtributed by the ſmalleſt arterial Veſſels, is by them carried into the *Bones* [1] and their Medulla, into the *Membranes* [2], *Muſcles* [3], *Fat* [4], Glands, and Skin; where vaniſhing through their exceeding Tenuity, they return again in reductory Veſſels, gradually enlarging; by which the arterial Blood and Juices are again returned through the Veins of the Hand to thoſe of the Arm and Shoulder, and from thence by the Cava to the Heart.

[1] All the Bones are on every Side inveſted, except at the Inſertions of their Ligaments and Capſules, with a Membrane call'd therefore Perioſteum; which is a reticular Plexus or Intertexture of an infinite Number of ſmall ſanguiferous Arteries and Veins, as well as Nerves and Lymphatics: But from the larger of theſe ſanguiferous Arteries ariſe ſmaller ones, which penetrate to the interior Fabric of the Bones, and enter betwixt their Lamellæ, throughout every individual Part. But beſides theſe Veſſels of the Perioſteum inveſting the Bones both without and withinſide, the Bones have alſo in their Cavities other larger, medullary Blood-

Blood-veſſels, which generally penetrate them thro' large Foramina in their Epiphyſes or Heads; which laſt Veſſels are not ſpent on the bony Lamellæ like the former, but are diſtributed on the medullary Loculi of the very fine cellular Membrane contained within the Bones for the Reception of the medullary Oil; which is alſo in Part ſeparated from the Arteriolæ of the internal Perioſteum, which inſinuates itſelf thro' the Foramina of the Epiphyſes Oſſium, with the larger Veſſels, and lines the Bones internally as the other Perioſteum does externally. As for the Blood brought into the Bones by thoſe Arteries, it is returned by correſponding ſmall Veins paſſing out through the oblique Foramina of the Bones, and opening into the adjacent Veins of the exterior Perioſteum, and thence it paſſes to the larger Trunks. Thus the Blood ſeems to have a twofold Circulation through the Bones; one from the Arteriolæ of the internal Perioſteum through the Pores, and betwixt the Lamellæ of the Bones; the other from the Arteries, ſpent reticularly on the medullary Cells without entering into the compact Subſtance of the Bone; thus, for Example, in the Cranium, you will have a clear View of this twofold Circulation, by ſuppoſing the Brain to be the oily Medulla of a Bone; ſo that the Pericranium and Dura Mater which detach Arteries into the Lamellæ of the Bones, will repreſent the Perioſteum internum and externum; but the Pia Mater will denote that Part of the internal Perioſteum which ſupplies Arteries diſtinct both in Courſe, Origin, and Diſtribution from the preceding.

[z] All which are by *Ruyſch* demonſtrated to conſiſt of Fibres and ſmall Veſſels variouſly interwoven and interſecting each other.

3 The whole Compages of the Muſcles are compoſed of Fibres from the Nerves, which we have demonſtrated continuous with the Arteries (*per* §. 270 and 284.); upon which Fibres are again ſpread the Arteries, Veins, and Fat, tranſuding into the cellular Membrane from the Arteries; the diaphanous Fibres being manifeſtly the Production of the Nerves (*per* §. 440.), whence it is manifeſt, that the whole Subſtance of the Muſcle is continuous with the Arteries.

4 The Adeps, which is a fat Oil, paſſes mix'd with the Blood through the Arteries and Veins in all Parts of the Body, as is evident even to the Eye by the Microſcope; but from the ſmalleſt of thoſe Veſſels, at their Anaſtomoſes, it is depoſited into the Cells of the adipoſe Membrane, out of the Courſe of the Circulation. Where the ſmall Arteries and Veins unite by Anaſtomoſes, there are lateral Communications with the blind Oil Cells for the Reception of the Fat, which being lighter than the other Parts of the Blood will both move on ſlower and more oblique or laterally, ſo as to enter the Cells, while the more denſe Parts of the Blood proceed more in a right Line according to the Axis of the Arteriola, into the correſponding Vein. But no Juice has a greater Tenacity than Oil, and therefore it will not perſpire or be conſumed, but accumulated. Hence we may eaſily perceive how a Perſon may become of a monſtrous Bulk by mere Obeſity; and how a Perſon may become thin again by the mere Motion of the Muſcles only accelerating the Blood through its Veſſels, and at the ſame time expreſſing the Oil into them from its containing Cells? We can alſo from hence give a Reaſon why lean People have much and fat People but little Blood in their Veſſels. I have obſerved, after *Lewenhoec*, a ſmall Portion of a Muſcle

Muſcle from a lean Ox looked red and full of Blood, but a like Portion of the Muſcle from a very fat Sheep manifeſted no Appearance at all of Blood, but ſeemed a continued Maſs of Fat: Another time I dry'd a Muſcle from a very lean Plow-horſe, and viewing a Bit of it with a Microſcope, it appeared uniformly red and nothing elſe; but a Piece of the Muſcle from a fat Ox being prepared and examined in the ſame manner, ſhewed very little Redneſs by the Microſcope, but ſeem'd rather a mere Particle of Fat.

§. 307. For it muſt be obſerved, that the Extremity of every ſmall Artery is accompanied, in all Parts of the Body as well as in the Limbs, with a ſort of glandular Apparatus (approaching the Fabric of §. 250.) from whence a Veſſel ariſes, carrying off the different Humour hear ſeparated, whether it be ſerous, *lymphatic* [1], aqueous, or oily; by which Veſſel the ſaid Humour alſo returns again into the Veſſels, and mixing with the reſt of the Blood in the *Veins* [2], returns by them to the Heart: Such an Apparatus is proved from Dropſies of all kinds, and eſpecially the *Anaſarca* [3]; from a lymphatic Tumour or Swelling of thoſe Parts which have had their *Veins* [4] obſtructed by Ligature; from *fiſtulous* [5] Ulcers, *Hydatids* [6], *Phlyctenæ* [7], the *Itch* [8], Eruptions, or *Granula Hordacea* [9], frequently obſerved in the Fat of Pork and other Animals; from whence it alſo appears, that this ſecretory Apparatus is to be found alike *in all Parts* [10] of the Body.

[1] We evidently perceive that there is ſecerned every where a limpid Liquor like Lymph; but we are not aſſured that the Secretion is made by glandular Machines, ſince we only meet with their Appearance in Diſeaſes.

[2] Thus the Juices of ſeveral Kinds is returned into the Blood, to be again ſeparated from thence for the ſame Purpoſes.

[3] An Anaſarca is a Collection or Stagnation of an aqueous Humour, either in the Lymphatics or in the Cells of the Membrana Adipoſa, in whoſe Cells the Arteries ought only to depoſit Fat in a healthy State; but ſince there is no Part of the whole Body but what is liable to this Species of Dropſy, it follows, that there muſt be a ſort of glandular Apparatus in every Part, from whence the ſaid lymphatic Humours ariſe,

[4] We know, by Experiment, that a Ligature made on the ſanguiferous Veins of a Part occaſions the Lymphatics to ſwell and become viſible by the Accumulation of their Juices, which before had a Paſſage into and through the ſanguiferous Veins. This Experiment may be beautifully made by fixing a Ligature on the Vena Cava of a living Dog, as it was firſt performed by *Lower*, who, however ought not to have thence concluded, that therefore every Dropſy was ſeated in the Lymphatics, which only makes that Species deſcribed by *Hippocrates*.

[4] Fiſtulous Ulcers diſcharge a great deal of a Liquor which is neither like Blood nor Matter; eſpecially when thoſe Ulcers penetrate to the Perioſtia of the Bones. When a Surgeon makes a Fontanel by applying a Cautery to the Cranium, at firſt indeed the Blood follows, but in a Day or two afterwards it pours out a mere Lymph; whence

it

it follows, that there must be lymphatic Vessels there.

[6] Hydatids are round pellucid Tumours, formed by an aqueous Humour retained in a thin Membrane: Nor can they well be said to be no more than Varices of the Lymphatics; for they being obstructed dilate into a Sphere, whence it would seem that their Cells were at first spherical, but invisible before they were preternaturally distended by Disease. These Hydatids are often formed in the Uretus, and *Ruysch* has found the whole Liver turn'd into these Vesicles.

[7] Phlyctenæ are oblong, pellucid, and lymphatic Vesicles; being the true Varices or Aneurisms of the Lymphatics. They frequently happen in the Eyes and endanger their Sight; as happen'd to a young Student who came under me, being very solicitous to preserve his Sight: In this Patient I could observe, with a Microscope, that the Artery which is extended over the Pupil was much enlarged and distended into Protuberances or Aneurisms of this kind; therefore the Vessel being removed and opened by a Needle with a suspended or gentle Hand, the Water ran out and his Sight returned.

[8] Chiefly the Itch, which is formed of small Pustules, including a sharp Ichor under the Cuticle, and which excites an intolerable itching. For the small Vessels of the Cutis which lay before concealed under the Cuticle, become so distended in this Disorder as to be visible and irritated, either by some acrid Virus, or even Animalculæ, according to *Redi* and others. When the reticular Body of *Malpighi* has been eroded and consumed in the Itch it proves of the very worst Kind, and if that Erosion extends to the Skin itself it produces a Le-

proſy; but if it extends even through the Skin to the ſubjacent Membrana Adipoſa, it produces the direful Malady termed Lepra Arabum, frequent among the Inhabitants of *India*, *Arabia*, *Egypt*, and *Palæſtine*.

9 Swine are often liable to the Meaſles, which are round little Grains like Barley, full of a ſerous or thicker Juice, which ought in a healthy State to be only Fat or Oil. For that they are really Follicles of the cellular Membrane appears from the *Ruyſchian* Art of Injection, by which the ſmall cutaneous Arteries are fill'd ſo as to force the Liquor even into the Cells of the fat Membrane. And poſſibly the ſerous Arteries may alſo communicate in like manner with the Cells, if we could ſubject them to the ſame Experiment.

10 In ſome Parts the Juices brought by the Arteriolæ fly off inſenſibly in Form of Vapours, which are partly retained in Cavities of the Body, and partly exhaled into the Air.

§. 308. Next, that Part of the Blood which has a finer or looſer Texture, being thicker and leſs fluxile, is by the Laws of Hydraulics forced into the *deſcending* [1] Trunk of the Aorta, where the more ſimple Parts of the ſame Blood will enter the *intercoſtal* [2] Arteries, and after having performed its Office with great Celerity in the Muſcles of Reſpiration, it paſſes the quickeſt of any (but §. 305.) into the correſponding Vena Azygos, and from thence by the Cava to the Heart. By the admirable Contrivance and Diſpoſition of theſe Veſſels the *Circulation* [3] is render'd exceeding

free

free through them, without any Reſiſtance or Hindrance from the large Quantity already in the Vena Cava; ſince the Parts which diſcharge their Blood into that Vein, *viz.* the Interſtices of the Ribs, and moſt of the Membranes in the Thorax, will not bear any Obſtruction without the moſt imminent and preſent Danger of Life. For this Reaſon therefore the Vena Azygos *diſcharges* [4] itſelf in that Part of the Cava where it is the ſooneſt emptied into the right Auricle and Ventricle of the Heart in its Diaſtole; and for the ſame Cauſe the Paſſage from the Arteries into the Veins is here free and open: From whence one may underſtand the Reaſon of the quick Circulation through theſe Parts, and why ſo many of the moſt *acute* [5] Diſeaſes frequently infeſt them.

[1] From thence ariſe firſt the coronary Arteries of the Heart, then thoſe of the Pericardium, and next the Arteries of the Mediaſtinum. But it muſt be remarked, that in the human Body there is but one arterial Trunk, though in Brutes who go with their Necks pendulous there are two Trunks, one aſcending and the other deſcending, as *Ruyſch* has very juſtly aſſerted and ſhew'd in Oppoſition to *Bidlow*.

[2] The Intercoſtals ariſe from the Aorta at right Angles, and from thence paſs in the Channels of the Ribs, cover'd before by the Perioſteum; but they do not run through the Pleura, only in the cellular Membrane betwixt the Pleura and Perioſteum of the Ribs. *Ruyſch* has demonſtrated that theſe

theſe Arteries are ſpent in the intercoſtal Muſcles, Pleura, Cartilages of the Ribs, and even the Skin itſelf on thoſe Parts, as *Euſtachius* had long before obſerved, who, one ſhould think, could hardly have obſerved and traced ſo diligently the Branches of the Vena Azygos if he had not been acquainted with ſome Method of injecting them, which yet does no way appear.

3 It is altogether ſingular, and ſomewhat ſurpriſing that the Blood returned from all the external and internal Parts of the Organs of Reſpiration, both Viſcera, Membranes, and Muſcles, does not go to the Heart by the common Channel of the Vena Cava but by a peculiar Vein for that Office, termed *Vena ſine pari*. For the ſmall Veins of the Pericardium, Mediaſtinum, the ſubcutaneous Veins from the Outſide of the Thorax, thoſe of the Pleura, the Intercoſtals, thoſe of the Diaphragm, and Parts adjacent, and poſſibly ſome from the Liver which are leſs eaſily diſcovered; all open into the Vena Azygos, as the excellent *Euſtachius* firſt obſerved, who ſeems to have proſecuted Anatomy with Application and Exactneſs more than human. The Vein we now ſpeak of is large, and placed on the Right ſide of the Bodies of the Vertebræ and Vena Cava, a little above the Pericardium, and inſerts itſelf into the adjacent right Auricle. The Reaſon for which peculiar Vein to the Organs of Reſpiration ſeems to be this. Every Perſon is obliged to draw in and expel the Air again from their Lungs alternately, ſo long as they live; to perform which Action requires alſo an alternate Contraction and Relaxation of the intercoſtal Muſcles; whence it was abſolutely neceſſary there ſhould be a free Paſſage for the Blood from the intercoſtal Arteries through the Muſcles into

into the Veins, and that eaſily and without any Delay: But the Motion of Reſpiration greatly accelerates upon any Exerciſe of the Body (*per* §. 208.), ſince the Blood then returns quicker by the Veins to the Heart, which muſt therefore protrude it more ſwiftly through the Lungs; which accelerated Motion of the Lungs ſuppoſes an increaſed Action of the Parts employ'd in Expiration and Inſpiration; whence if the Blood of the intercoſtal Veins had paſſed immediately into the Cava, there would have been Danger of thoſe ſmaller Veſſels being over-charged, and diſtended or obſtructed, whenever the Blood was more than ordinarily accumulated in the Cava; whence the Parts which are in themſelves very ſenſible and prone to Inflammation, would have been much more ſubject thereto than they now are. Nature has therefore thus providently guarded againſt a fatal Pleuriſy, by furniſhing theſe Parts with a peculiar Vein, communicating with the upper and lower Cava, and receiving the Blood from the Organs of Reſpiration, to depoſit the ſame in the Cava when it reſiſts the leaſt, that is, when the Heart relaxes and takes the Blood of the Vena Cava and Azygos into its right Auricle and Ventricle. Hence therefore it appears, that the Ancients did not without Reaſon place the Seat of a Pleuriſy in this Vein, which they ſtudiouſly endeavoured to empty in that Diſorder; for though the Seat of Inflammation is not in Veins, yet in this Part it is not far from them, *viz.* in the Reſiſtance given by theſe diſtended Veins to the intercoſtal Arteries. Add to this, that the Veins before deſcribed are all deeply ſituated out of the Influence of any Irregularities from the unconſtant Actions of the voluntary Muſcles.

Both

[4] Both the Inſertions of this Vein are furniſhed each with a Valve at their Entrance in the Cava.

[5] There are ſcarce ten People who periſh by acute Diſeaſes, but nine of them die pleuritic; not only from the Shortneſs of the Veſſels and Vicinity to the Heart, but alſo from their greater Repletion, by removing the Preſſure of the Air from them in Inſpiration, by the Stimulus of theſe Muſcles continually in Action, from the Nearneſs of the cold Air inſpired, and from the Swiftneſs of the Blood's Circulation here, *&c.* which diſpoſe a ſizy or inflammatory Blood more to ſhew its Effects in theſe Arteries than in others.

§. 309. After theſe the *phrenic* [1] Arteries, with the Pericardio-diaphragmatics, receive the like Blood with the intercoſtal and vertebral Arteries, through which the Blood circulating very ſwiftly into the phrenic Veins, paſſes from them into the Cava; whence theſe Veſſels alſo conſpire to render the Return and Circulation of the Blood, free, ſwift, and conſtant.

[1] The Ancients gave the Name φρενες to that Part which we now call the Diaphragm; becauſe they imagin'd that the Mind reſided there in a particular manner: But the Diaphragm has ſome Arteries from thoſe of the Mediaſtinum, and others from thoſe of the Pericardium, as *Ruyſch* has demonſtrated; all which various Arteries communicate together, as the Pericardium is cloſely attached to a great Part of the Diaphragm; from which communication the Circulation is again rendered

rendered more free; which was the more neceſſary as the Part is ſo liable to Inflammation, the Pleuritis and Peripneumonia being hardly ever obſerved without ſome degree of the Paraphrenitis, which ſeldom ariſes of itſelf but from one of the former. From the Connection of the Diaphragm one may underſtand why ſuch an intolerable Heat is perceived there when it is diſorder'd; and why, when the Diaphragm is inflamed, the Pericardium and Parts adjacent generally partake of the Diſorder by the Communication of their Arteries. The Blood of theſe Parts ſeldom returns by the Vena Azygos of *Euſtachius*, which he indeed obſerved, but I never yet ſaw it; and though *Euſtachius* refers the phrenic Veins to the Azygos, they are generally referred to the Cava by Anatomiſts.

§. 310. The deſcending Aorta paſſing next through the Diaphragm, ſends its Blood (agreeable to §. 306 and 307.) to the Loins, Abdomen, Thighs, Legs and Feet, from whence the Blood returns again by the Veins, furniſhed with *Valves* [1] in the lower Parts of the Body.

[1] The Blood of the lower Limbs meets with a very difficult Return to the Heart, as moving ſlower than the reſt, and againſt its own Weight: If indeed the Aorta and Cava communicated as openly as the two Legs of a Syphon, the perpendicular Weight of the Blood deſcending in the firſt would counterpoiſe that aſcending in the laſt; but the infinite Ramification of thoſe Veſſels betwixt their Trunks, break off the Force of the Heart, Aorta, and Arteries, and the Blood returns

turns but very ſlowly upwards in the Veins; in weak Veſſels it is retarded by its own Weight, and often diſtends the yielding and weak Coats of the Veſſels into Varices: But to alleviate theſe Inconveniences, in ſome meaſure, Nature has ſupplied thoſe Veins of the lower Extremities, which moſt require them, with Valves, which ſuſtain the Weight of the ſuperior Blood from preſſing on the inferior; ſo that by dividing a large venal Tube as it were into ſo many ſmaller ones by Valves, the Blood will both be propell'd by the Re-action of the elaſtic Valves, preſſed by its Weight, and the contractile Force of the adjacent Arteries and Muſcles will have a greater Power to ſend it forwards in ſmall Parcels than if it was in a continued perpendicular Cylindar.

§. 311. Now from the ſame deſcending Trunk of the Aorta below the Diaphragm, ariſe *Arteries* [1] which are ramified to all the *Viſcera* [2] of the Abdomen, in which they are formed or diſpoſed nearly into a glandular Fabric, and may be commodiouſly diſtinguiſhed into thoſe Branches which ſerve to the Formation of Chyle, termed *Chylopœtic* [3]; thoſe for the Secretion of Urine, termed *Ouropœtic* [4]; and thoſe for the Separation of Semen, termed *Spermatopœtic* [5].

[1] Theſe are reducible to three capital Trunks, of which the firſt is (1.) the *Cœliac* Artery, ariſing from the Aorta immediately below the Diaphragm; (2.) the *Meſentrica ſuperior*; and (3.) the *Meſentrica inferior*: From which three Arteries

ries all the abdominal Viſcera are ſupplied with Blood.

[2] By a Viſcus we underſtand an organic Part of the human Body, which receiving the arterial Blood, does, by the Power of its Fabric, work ſome Change therein, and then returns the ſaid Blood again to the Heart by the Veins. Theſe Viſcera of the Abdomen are contained within the Peritonæum, that is, wrapped up in the Duplicatures thereof, and not contained in it as in a Bag: For the Peritonæum being extended from the Loins over all the Viſcera, forms as it were a diſtinct Bag to receive each, ſo that there are in reality as many Duplicatures or Sacculi of the Peritonæum as there are Viſcera, except the urinary Parts, which are without the Peritonæum, and covered by it only on their Foreſide.

[3] The *Chylopœtic* are thoſe of the Liver and Spleen, Omentum, Stomach, Pancreas, Meſentery, Inteſtines, with the meſenteric Glands, and the three Kinds of Veſſels before enumerated.

[4] The *Spermatic* are thoſe of the Teſticles and ſeminal Veſicles in Males; and in Women thoſe of the Uretus, the Ovaria, and their mothwing'd Expanſions, with the Plexus's extended to the Thighs, and their Veſſels.

[5] The *Ouropœtic* are thoſe of the Kidneys and their Glandulæ or Capſulæ Atrabilariæ, with the Emulgents. But of all theſe Arteries we muſt begin firſt with thoſe that come firſt from the Aorta, and are diſtributed into the chylificative Viſcera, *viz.* the cœliac Artery and its Branches, among which we are again to begin firſt with the Branches going to the Spleen, becauſe the Blood

Blood muſt be firſt prepared in that Body before it goes to the Liver, and therefore the Action of the Liver cannot be well underſtood before we have ſurvey'd that of the Spleen, which is an Organ that does not work for itſelf but for the Good of others, ſerving for a Purſe or Sieve, to which the Emperor *Trajan* formerly compared it with a great deal of Juſtice.

F I N I S.